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MILITARY INTERFACE STANDARD

AIRCRAFT DISPLAY SYMBOLOGY

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DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FOREWORD

1. This Military Interface Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASC/ENSI, Wright-Patterson AFB OH 45433, by using the Standardization Document Improvement Proposal (DD Form 1426) at the end of this document, or by letter.

3. This standard is written for use by the project engineer in a military procuring activity who is specifying a new system or subsystem design.

4. This standard is formatted to draw attention to aspects of the design where tailoring of requirements is necessary or possible. The figures shown herein are intended as examples and need not be duplicated exactly for each application. Each requirement is discussed in the appendix.

5. This document replaces MIL-STD-884, Electronically or Optically Generated Displays for Aircraft Control and Combat Cue Information.

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MILITARY INTERFACE STANDARD
AIRCRAFT DISPLAY SYMBOLOGY

1. SCOPE

1.1 Scope. This standard describes symbols, symbol formats, and information content for electro–optical displays that provide aircrew members with information for takeoff, navigation, terrain following/terrain avoidance, weapon delivery, and landing. It describes symbol geometry, font, recommended dimensions, and mechanizations. This document also defines the symbology requirements for a primary flight reference and describes some fundamental relationships between symbol motion and aircraft system states.

This standard does not describe symbols for electronic warfare displays which are normally classified in meaning. It does not describe qualities (other than those mentioned above) that affect legibility, such as resolution, brightness, uniformity, contrast, flicker, noise, minimum line movement, color, and the like.

1.2 Application. This symbols in this standard apply to displays used on military aircraft.

1.3 Use. This standard should not be used for contractual purposes until all tailoring decisions have been made and incorporated into the wording. In tailoring each requirement of sections *4* and *5*, the corresponding guidance in the appendix should be considered. The requirement for a standard primary flight reference can be incorporated into a contract by requiring primary flight reference displays and symbology as defined in section *4.1*.

1.4 Deviation. In the event a projected design for a given application results in improved system performance, reduced life cycle cost, or reduced development cost through deviation from this standard, or where the requirements of this standard result in compromise in operational capability, the issue shall be brought to the attention of the procuring activity for consideration of change.

2. APPLICABLE DOCUMENTS

2.1 Government documents

2.1.1 Specifications and standards. Unless otherwise specified, the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this standard to the extent specified herein.

SPECIFICATIONS

Military

AFGS–87213 Displays, Airborne, Electronically/Optically Generated

(Specifications may be added to this list when tailoring the document. Appendix section 20 may list applicable specifications.)

STANDARDS

Military

(Standards may be listed here when tailoring the document. Appendix section 20 may list applicable standards.)

(Unless otherwise indicated copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111–5094.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this specification to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

(References may be listed here when tailoring the document. Appendix section 20 may list other applicable documents.)

(Copies of publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Non–Government publications. The following document(s) form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation.

(Publications may be listed here when tailoring the document. Appendix section 20 may list applicable non–Government publications.)

(Application for copies should be addressed to [name and address of the source].)

(Non–Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 Display definitions

3.1.1 Center total field of view (CTFOV). Center total field of view (CTFOV) is located at the center of the HUD's total field of view.

3.1.2 Electronic attitude director indicator (EADI). The EADI is a replacement for the standard ADI, but with no moving parts other than controls and switches. The EADI presents the symbols on a display using either a CRT or direct view flat plate technology. Basic information consists of attitude, altitude, and air speed. Other information can be presented depending upon mode requirements and displayed by mode selection, e.g., ILS, NAV, weapon release, etc.

3.1.3 Head–up display (HUD). The HUD is a display which projects collimated symbolic information into the aircrew member's forward field–of–view (FOV). The technique results in the combination of flight control and weapon delivery information with external visual cues from the scene normally viewed through the windscreen. Specific symbols and formats can be selectable for a given mode of operation. HUD display information must be compatible with head–down display information. Take–off, landing, navigation, terrain following/avoidance, air–to–air and air–to–ground weapon delivery modes may be provided. Video formats may also be displayed, such as TV, FLIR, or electronically created video along with symbology.

3.1.4 Helmet–mounted display (HMD). The HMD is a display which projects video imagery, symbolic and/or alphanumeric information on a display medium (e.g., combining glass or visor) into one or both eyes of the aircrew member. In most applications the display medium is attached to a flight helmet which is part of a head tracking system. The line of sight of the helmet is determined by the head tracking system and a designated sensor is slewed in a one–to–one angular correspondence with this line of sight. The display medium then displays the image from the designated sensor: television (TV), forward looking infrared (FLIR), or electronically created video. Specific symbols and formats can be selectable for a given mode of operation.

3.1.5 Horizontal situation display (HSD). An HSD is a display which aids the crew members in navigation. It consists of a plan view presentation of heading, distance–to–go, bearing–to–destination or some other navigation reference, ground track, course, aircraft position, and steering error. Modes may consist of manual, north–up, track–up, data, test, and off. Selection of map scale factors may also be provided. Navigation update can be accomplished with the proper computer techniques. Some HSDs can display moving map video as a background for the symbology. Symbols may be used to annotate check points, various legs of the mission, high risk areas, ground track deviation, and radar threat warning, etc. Specific modes and formats can be selectable for a given mode of operation.

3.1.6 HUD reference points – All the HUD's symbology is referenced against either one of four fixed reference points or other HUD symbols. The four fixed reference points are the center total field of view, the aircraft reference point, left hand reference point, and the right hand reference point.

a. **Aircraft reference point (ARP)** is defined as the point on the HUD that a line, which extends from the design eye point and is parallel to the aircraft reference line, passes through. The Climb–Dive Marker and Flight Path Marker are referenced from this point.

b. **Left-/right-hand reference points (LHRP/RHRP)** are a movable point against which the airspeed and altitude scales are positioned. The LHRP and RHRP always have the same vertical position and are of equal horizontal distance from a vertical line running through the CTFOV. The vertical positions are chosen to keep the climb–dive marker between the airspeed and altitude scales during normal cruise flight and approach and landing modes. Their horizontal distance is chosen to ensure their visibility within the IFOV and to establish an effective crosscheck distance.

3.1.7 Multifunction display (MFD). The MFD is a general purpose display which may be used in many places in the cockpit. In addition to the modes listed for the HSD and VSD, other possible modes are energy management, engine management, aircraft subsystem information, and integrated test and maintenance. Specific modes and formats can be selectable for a given mode of operation. It is sometimes called a Multipurpose Display (MPD).

3.1.8 Vertical situation display (VSD). The VSD has all of the features of an EADI, with the increased capability of displaying sensor data. Additional modes may consist of TV, infrared (IR), attack radar, weapon TV, or terrain following radar. Specific symbols and formats can be selectable for a given mode of operation. When any mode other than one of the primary EADI modes is selected, the VSD may present basic symbolic information for flight control superimposed on the sensor data. VSD formats generally do not use sky/ground shading.

3.2 Information definitions (from *MIL-STD-1295* and *MIL-STD-884*)

3.2.1 Coding characteristics. Coding characteristics are readily identifiable attributes commonly associated with a symbol by means of which such symbols are differentiated; i.e., size, shape, color, etc. See *MIL-STD-1472* for more information on coding requirements.

3.2.2 Command information. Command information is displayed information directing a control action.

3.2.3 Milliradians (mr). A radian is a unit of plane angular measurement equal to the angle at the center of a circle subtended by an arc equal in length to the radius. A mr equals one thousandth of a radian.

3.2.4 Mode. A mode is the functional state of the display and/or control system(s). A mode can be manually or automatically selected.

3.2.5 Occlusion. (Sometimes called sparing.) The blocking of one symbol by another. For example, the altitude display has higher occlusion priority than the horizon line, so the piece of horizon line which would overwrite the altitude display (plus about a 2-mr margin) is not written to the screen when the aircraft attitude would cause them to intersect.

3.2.6 Predictive information. Predictive information is information predicting future status, condition, or position of the aircraft, a system, or a subsystem.

3.2.7 Primary flight data. Instrument flight information required to support the execution of specific instrument flight maneuvers (See Table 1). The basic intent of Primary Flight Data is two–fold:

1. Provide the pilot or cockpit crewmember with the most accurate, intuitive and complete set of flight instrument symbology necessary and sufficient to accomplish any portion of the mission.

2. Minimize the amount of eye movement needed to integrate all the required flight instrument information for the safe accomplishment of the mission.

3.2.8 Primary flight instrument. A primary flight instrument is any display or instrument that serves as the pilot's primary reference of some instrument flight information. A centrally located attitude directional indicator (ADI) can be considered a primary flight instrument because it is the pilot's primary reference for pitch, bank and command steering information.

3.2.9 Primary flight reference (PFR). A primary flight reference is any display or suite of displays or instruments that provide all required information for instrumented flight and complies with the *MIL-STD-1787* requirements for information content and presentation.

3.2.10 Qualitative information. Qualitative information is information presented by a display in a manner which permits the display user to assess the information without requiring attention to an exact numerical quantity.

3.2.11 Quantitative information. Quantitative information is information presented by a display in a manner which permits the display user to observe or extract a numerical value associated with the information. It may be displayed in either digital or analog formats.

3.2.12 Single medium primary flight reference. A single display medium (i.e., MFD, HUD, HMD, etc) that complies with all the requirements of a primary flight reference. The term single–medium should never be confused with the term single/sole source. The word source refers to the subsystem or sensor at which the flight instrument information originates. Therefore, a single/sole source display implies that the information presented on the display is generated from a single source. With today's integrated avionics, it is uncommon and unwise, to depend solely upon a single source for such critical information. The development of the Mil–Std 1787 baseline symbology set was to establish the HUD as a single–medium primary flight reference. Simply stated, this means that the Air Force now officially recognizes and endorses the use of the HUD as a primary means of presenting flight instrument information.

3.2.13 Status information. Status information is current condition information about the aircraft system and its surroundings.

3.2.14 Symbol. A symbol is a geometric form or alphanumeric information used to represent the state of a parameter on a display.

$$17.45 \text{ mr} = 1 \text{ deg}$$
$$1 \text{ mr} = .0573 \text{ deg}$$
$$1 \text{ mr} = 3.44 \text{ min}$$
$$1 \text{ min} = .291 \text{ mr}$$

3.2.15 Symbol size. Actual symbol size on a direct view display based on design eye distance from the display can be calculated using the following formula:

$$2D \tan (a/2) = L$$

L = size of symbol at display
D = design eye distance from the display
a = symbol subtense (degrees)

Example: The breakaway symbol is 100 mr in length. What is the size of the symbol at the display in cm, if the design eye distance is 28 inches (71 cm)?

$$100 \text{ mr X } \frac{0.0573 \text{ deg}}{\text{mr}} = 5.73 \text{ degrees}$$

$$2(71) \tan (5.73/2) = L \text{ t } L = 7.11 \text{ cm}$$

This formula does not apply for head–up displays. Computer ray traces of a HUD optics train are required to determine symbol size on HUD CRTs. See *AFGS–87213* for the measurement procedures used to verify symbol size on head–up and head–down displays.

3.3 Abbreviations and acronyms

A/A – air–to–air
A/G – air–to–ground
ASE – allowable steering error
ASL – azimuth steering line
BFL – bombfall line
CCIL – continuously computed impact line
CCIP – continuously computed impact point
CCRP – continuously computed release point
CDI – course deviation indicator
CDL – climb/dive ladder
CDM – climb/dive marker
CTFOV – center total field of view
EADI – electronic attitude director indicator
EO – electro-optical
FLIR – forward looking infrared
FOV – field of view
FPM – flight path marker
GHL – ghost horizon line
HSD – horizontal situation display
HSI – horizontal situation indicator
HUD – head–up display
Hz – hertz
IFOV – instantaneous field of view
ILS – instrument landing system
IP – initial point
LCOS – lead computing optical sight
Ldg – landing
LHRP – left-hand reference point
LOS – line of sight
mr – milliradians
Nav – navigation
PFR – primary flight reference
PPI – plan position indicator
RHRP – right-hand reference point
R_{max} – range, maximum
R_{min} – range, minimum
TAA – target aspect angle
TACAN – tactical air navigation
TD – target designator
TF – terrain following
TFOV – total field of view
TISL – target identification set, laser
TOF – time of flight
VDI – vertical deviation indicator
VFOV – vertical field of view
VSD – vertical situation display

4. REQUIREMENTS

4.1 Information content of the display. Displays shall present information needed for all instrument flight maneuvers to include takeoff, navigation, and landing. Symbols and symbol formats shall be integrated with emphasis on enhancing the pilot's spatial orientation and situational awareness while minimizing display clutter, particularly when visibility is poor.

4.1.1 Primary flight reference (PFR) data. All pilot crew stations from which a pilot is to control an aircraft shall have at least one complete set of PFR data meeting the following requirements: A PFR shall provide the pilot flying the aircraft with the information required to accomplish an instrument maneuver during a mission segment and shall enable the pilot to maintain attitude awareness and to recover from an unusual attitude. A single-medium primary flight reference shall present the required information on a single medium such as a multifunction display, head-up display, or helmet-mounted display. The PFR shall be a prominent, centrally located display.

a. Location. A complete set of primary flight data shall be presented either head up or head down at all times. If the primary flight data is located head up, a head-down presentation shall be immediately available from only one hands-on switch action by the pilot. A head-up PFR shall subscribe to location criteria for head-up displays. The head-down PFR shall be centrally located within the pilot's normal scan pattern on the instrument panel. Vertical stacking on top of the primary navigation display is preferred; however, a side-by-side arrangement with the PFR on the left is acceptable. If both a head-up and head-down PFR are presented, the head-down PFR shall be located on the instrument panel as previously described and within 25 degrees of the horizontal axis of the center of the HUD field of view (FOV) (*Figure 1a*).

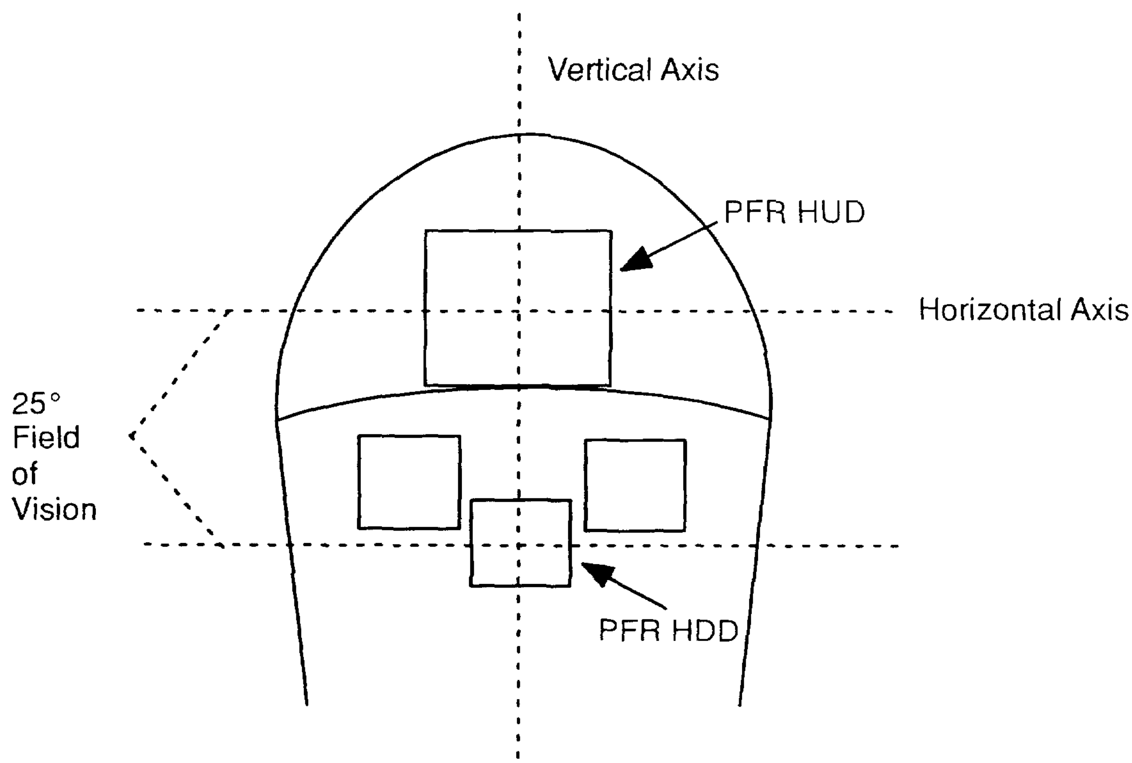


FIGURE 1. a. Preferred location of head-up and head-down primary flight reference displays.

b. Critical flight data. A PFR shall always provide the following critical flight data:

(1) Climb/dive angle (pitch and vertical velocity if a single symbol representing the climb/dive angle is invalid or unavailable) shall be centrally located within the PFR and shall provide the crew member with a minimum coverage angle of ________.

(2) Bank
(3) Altitude
(4) Airspeed

c. Data for instrument maneuvers. When the following data is required for an instrument maneuver it shall be provided in the PFR:

(1) Heading
(2) Bearing
(3) Distance
(4) Lateral and vertical deviation from a selected course and glide path
(5) Flight director and an indication of absolute altitude (category II and III approaches)
(6) Angle of attack
(a) and sideslip
(b) when required by aircraft design

d. Supplemental flight data. The following information is not required in the PFR but shall be in the viewing area of the pilot flying the aircraft:

(1) Power indication
(2) Altimeter setting (when monitoring barometric altitude)
(3) Selected course
(4) Timing

e. Non-PFR data. Additional information included on the display(s) containing the PFR shall not interfere with maintaining attitude awareness or recovering from an unusual attitude.

f. Failure indication. Failure indication of any required data shall be provided in the PFR.

g. Declutter. Symbols that can be deleted by decluttering should have a secondary warning when they are deleted because of faulty data.

4.2 Standard symbols. Symbols for the functions described under 4.2 shall have the geometry shown in the figures accompanying each paragraph in the standard.

4.2.1 Aircraft reference symbology

4.2.1.1 Climb/dive marker. The climb/dive marker (CDM) (*Figure 2a*) shall display the current climb/dive angle when read against a climb/dive ladder. The CDM shall be free to move along the vertical axis within the instantaneous field of view (IFOV) to present the climb/dive angle accurately. If the aircraft's climb/dive angle requires the positioning of the CDM outside the limits of the display's IFOV, the CDM shall be limited and replaced by the dashed climb/dive marker (*Figure 2b*). The CDM or dashed CDM shall be visible within the display's IFOV at all times.

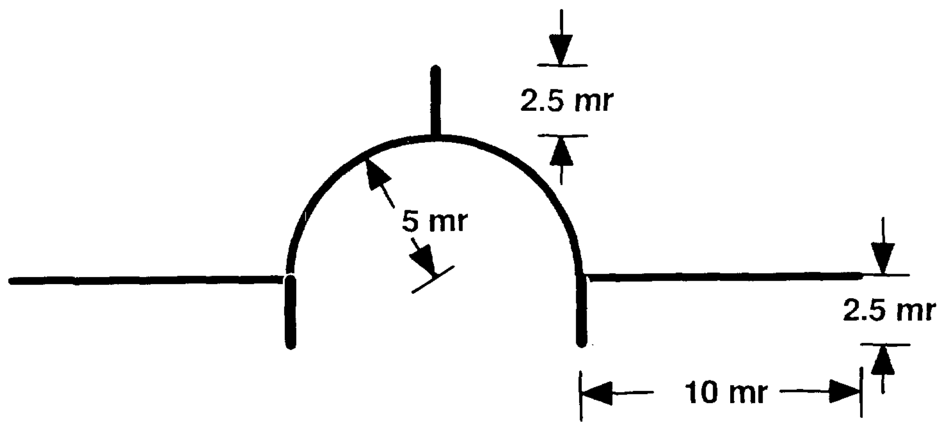


FIGURE 2. a. Climb/dive marker (CDM).

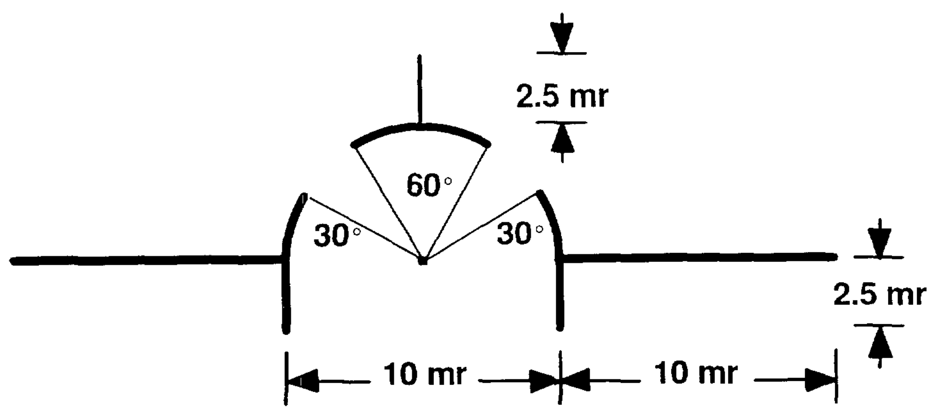


FIGURE 2. b. Dashed climb/dive marker.

4.2.1.2 Flight path marker. The flight path marker (FPM) (*Figure 3*) shall indicate the actual flight path of the aircraft when read against the outside world. The symbol shall be quickened and free to move within the limits of the HUD's total field of view (TFOV).

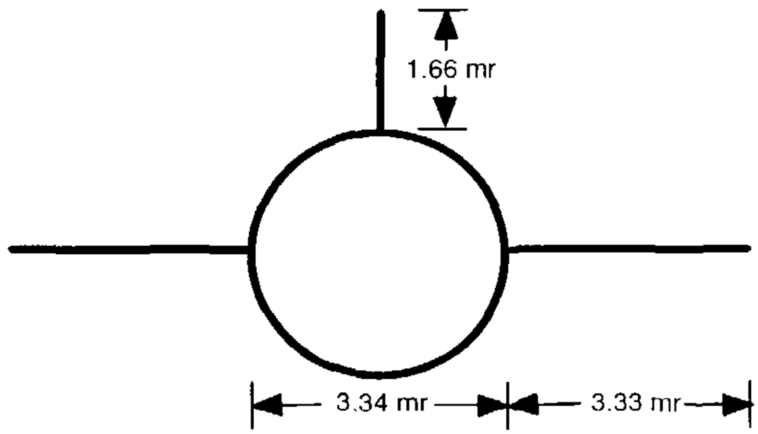


FIGURE 3. Flight path marker.

4.2.1.3 Climb/dive ladder. The climb/dive ladder (CDL) shall display the aircraft's climb/dive and roll angle when read against the CDM. The CDL shall be a continuous scale consisting of the true and ghost horizon lines, climb/dive bars with numerical labels, and the zenith and nadir symbols. CAUTION: Pitch reference ladder horizon is no longer accurate to the real world.

4.2.1.3.1 Horizon line. The horizon line shall be incorporated into the CDL scale at the zero climb/dive angle position to provide a horizontal reference point. The horizon line shall be a bold line that extends the entire width of the HUD TFOV with a 32-mr gap in the center. The horizon line shall be occluded by the speed and altitude scales. The horizon line shall be displayed whenever it is within the limits of a circle defined by the IFOV. Otherwise, the ghost horizon line shall be displayed.

The ghost horizon line (GHL) shall provide a horizon reference any time the true horizon line is outside the limits of the IFOV. The GHL shall be presented as a bold, dashed line extending the entire width of the HUD TFOV. The line shall be positioned on the tangent of a circle about the center total field of view (CTFOV) and parallel to the horizon. Whenever the CDM is near the GHL, the radius of the circle shall be increased to maintain a minimum separation of 20 mr between the CDM and GHL.

4.2.1.3.2 Climb/dive bars. The climb/dive bars make up the CDL to display the aircraft's climb/dive angle when read against the CDM. The climb/dive bars shall consist of 11 solid climb bars and 11 dashed dive bars. The bars shall be positioned at 5-degree intervals from 5 to 30 degrees and at10-degree intervals from 40 to 80 degrees.

To help distinguish between the climb and dive portions of the CDL, the wings on the dive bars shall be bent or sloped by one-half of the dive angle they represent.

4.2.1.3.2.1 Climb bars. The climb bars shall display the aircraft's climb angle when read against the CDM.

The climb bars shall consist of two 30-mr lines separated by a 32-mr gap with 5-mr vertical lines extending off each end. Numerical labels ranging from 5 to 80 shall indicate the degrees and shall be located on the lower left side of the respective climb bars (*Figure 4*).

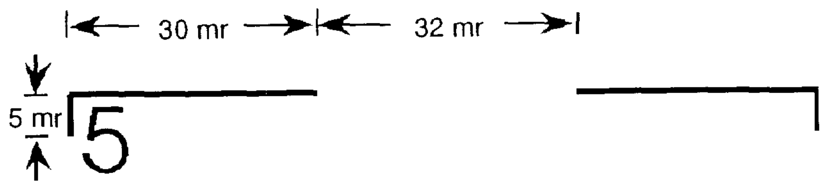


FIGURE 4. *5-degree climb bar.*

4.2.1.3.2.2 Dive bars. The dive bars shall display the aircraft's dive angle when read against the CDM. The dive bars shall consist of two 30–mr dashed lines separated by a 32-mr gap. The bars shall be bent by one-half of the dive angle (e.g., the 40-degree dive bar has 20 degrees of slope). Numerical labels ranging *from –5 to –80 shall* be located on the upper left side of the respective dive bars (*Figures 5* and *6*).

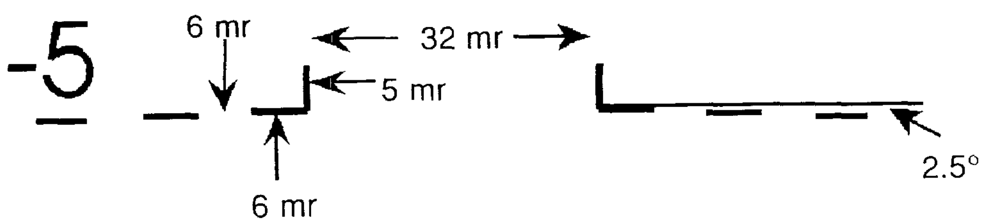


FIGURE 5. 5-degree dive bar.

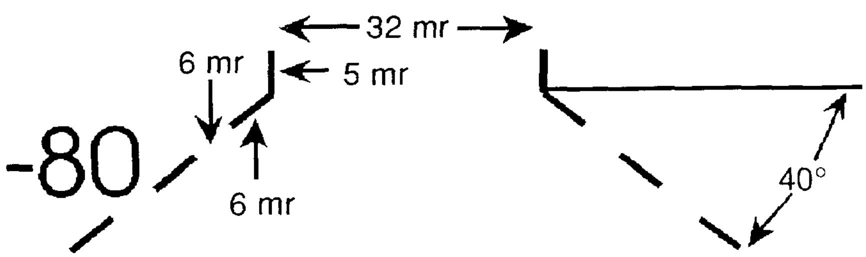


FIGURE 6. 80-degree dive bar.

4.2.1.3.3 **Zenith symbol.** The zenith symbol (*Figure 7*) shall display the highest possible climb angle (i.e., 90 degree climb angle). The zenith symbol shall always rotate to point toward the nearest horizon.

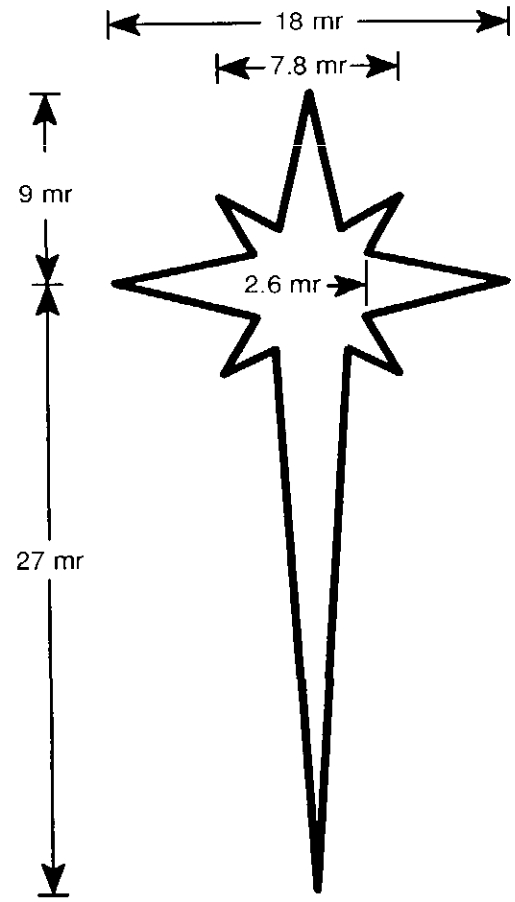


FIGURE 7. Zenith symbol.

4.2.1.3.4 Nadir symbol. The nadir symbol (*Figure 8*) shall represent the lowest possible dive angle (i.e., 90 degree dive angle). The nadir symbol is always rotated to point toward the nearest horizon.

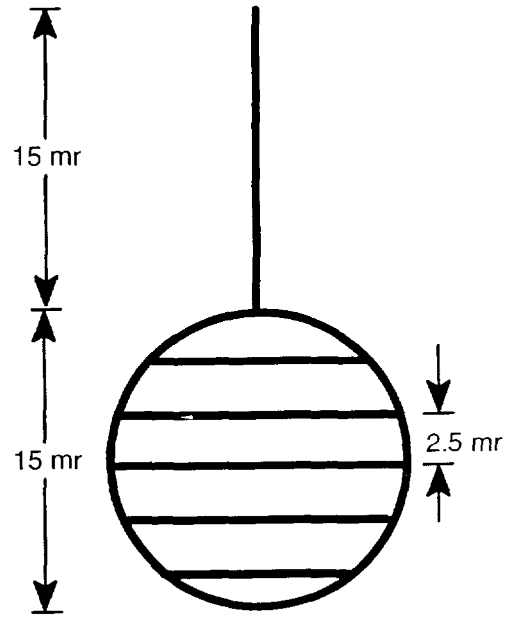


FIGURE 8. **Nadir symbol.**

4.2.1.4 Longitudinal acceleration cue. The longitudinal acceleration cue (LAC), when read against the CDM, shall provide an indication of the aircraft's acceleration along its flight path (*Figure 9*).

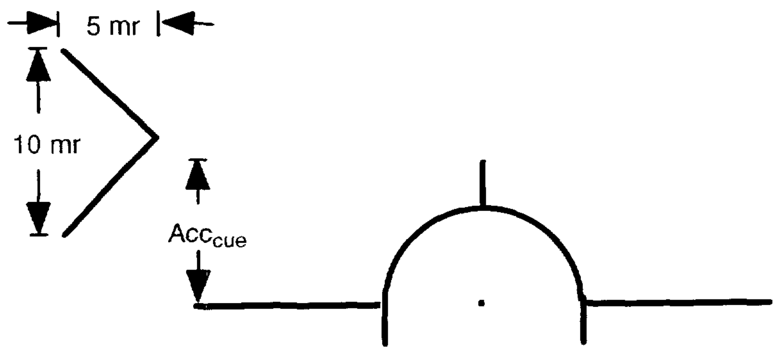


FIGURE 9. Longitudinal acceleration cue.

4.2.1.5 **Speed worm.** The speed worm (*Figure 10*) shall indicate deviation from the aircraft's on-speed angle of attack. This symbol shall be located on the left wing of the CDM and remain vertical in relation to the CDM. The worm is a rectangle that varies in height above or below the CDM wing. The speed worm shall be displayed when the HUD is in instrument landing system (ILS) mode or landing gear is down.

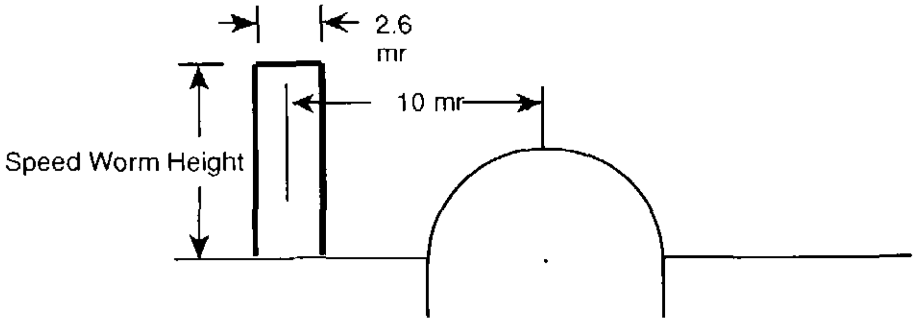


FIGURE 10. Speed worm.

4.2.1.6 **Aircraft pitch reference symbol.** The pitch reference symbol (also known as the miniature aircraft symbol) shall be in a fixed location on the display, referenced to the aircraft fuselage datum. The apex of the W shall be aligned with the wings and the symbol shall be laterally centered. Occlusion priority is high. (*Figure 11*)

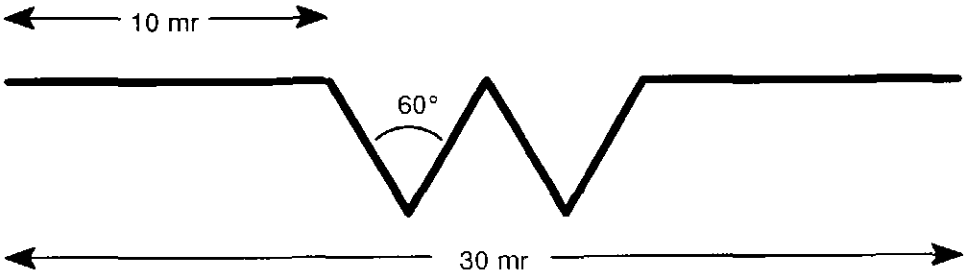
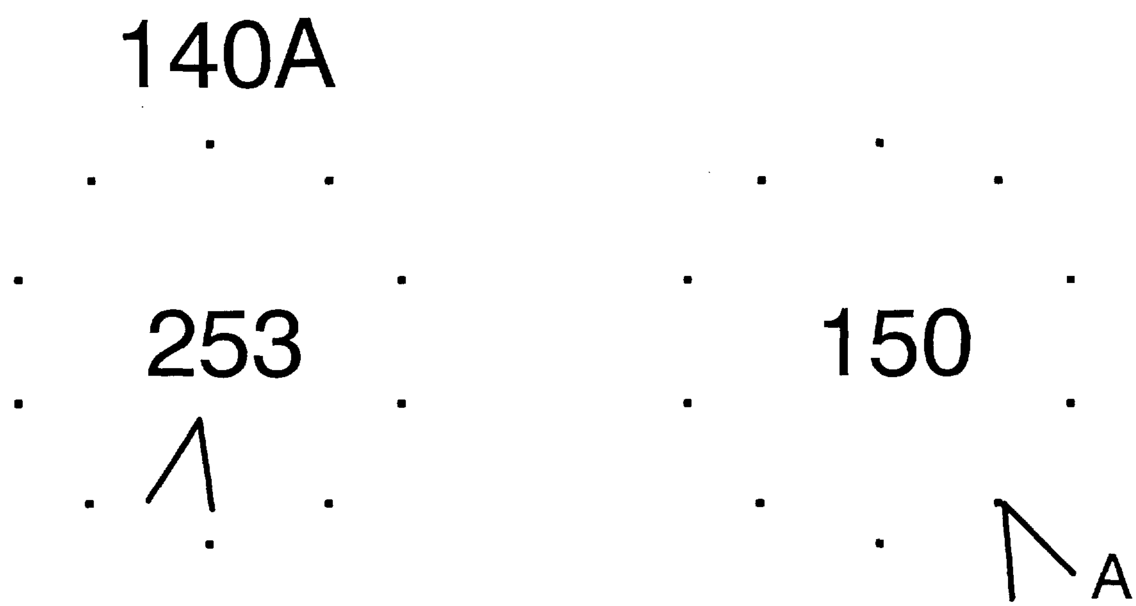


FIGURE 11. Aircraft pitch reference.

4.2.2 Scales. Scales shall be used to display the aircraft's speed, barometric altitude, heading, and bank. All scales, except the bank scale, shall be positioned against the left- and right-hand reference points (LHRP and RHRP). The bank scale shall be centered around the CTFOV.

4.2.2.1 Airspeed scale. The speed scale (*Figure 12*) shall display the aircraft's current and commanded speeds. The speed scale shall consist of a dial with index, commanded speed caret, and various readouts. The readouts shall include the current speed and appropriate commanded speeds. The center of the speed dial shall be positioned at the LHRP. The type of airspeed displayed (indicated or calibrated) shall be that which the aircraft is normally flown and shall not include any associated letters. This display shall be presented full time on the primary flight reference (PFR).

The current speed shall be displayed as a digital readout at the center of the dial. The commanded speed readouts shall be displayed above the dial whenever the difference between the current speed and the commanded speed is greater than 40 knots. The commanded speed caret shall be displayed on the dial whenever the aircraft's speed is within 40 knots of the commanded speed.



a. Current and commanded speeds displayed.

b. Current speed and commanded speed caret displayed.

FIGURE 12. Airspeed scale.

4.2.2.1.1 Airspeed dial. The speed dial (*Figure 13*) shall consist of 10 dots equally spaced around an 18-mr circle with a 7-mr index located 9 mr from the center of the dial. The index shall make one complete clockwise revolution for every 100 knots of increasing speed. The center of the speed dial shall be positioned at the LHRP.

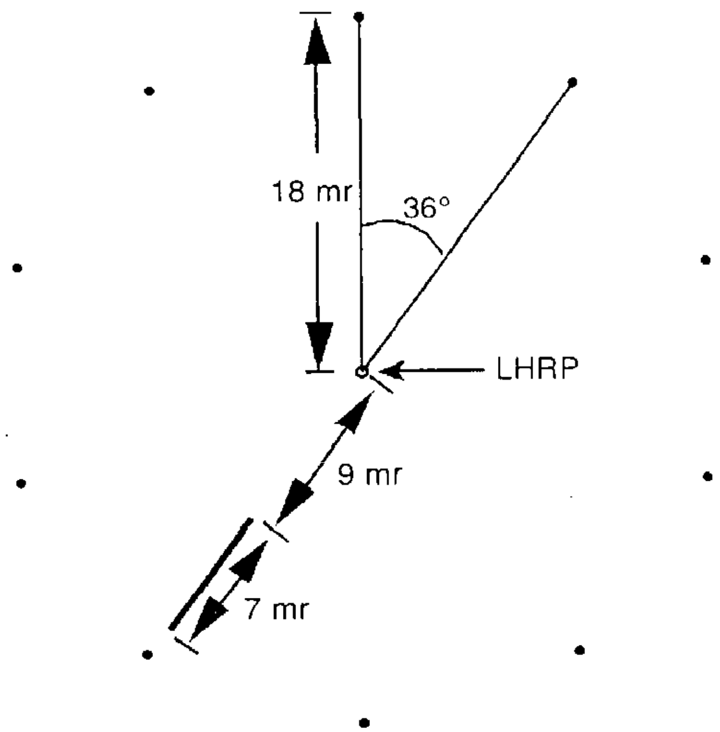


FIGURE 13. **Speed dial.**

4.2.2.1.2 Airspeed readout. The speed readout, composed of three digits, shall be displayed in the center of the speed dial. All digits shall be full size (7 mr high by 4 mr wide), and leading zeroes shall be displayed as blank spaces. The resolution of the display shall be to the nearest knot.

999

4.2.2.1.3 Commanded speed caret. The commanded speed caret (*Figure 14*) shall point to the commanded speed whenever the difference between the current speed and the commanded speed is less than 40 knots. The caret shall be located on the outside edge of the speed dial pointing inward.

A 60 percent sized letter shall appear next to the caret to identify which commanded speed is being indicated by the caret.

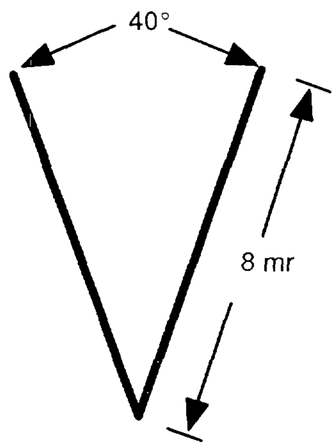
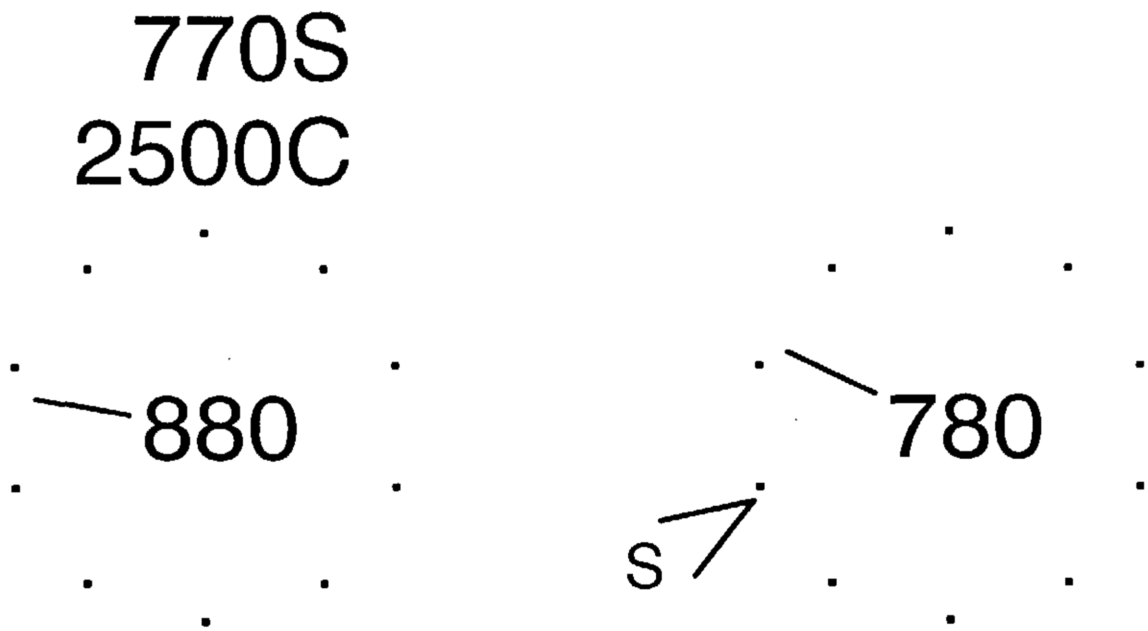


FIGURE 14. Commanded speed caret.

4.2.2.1.4 Commanded speed readouts. The commanded speed readouts shall display the various commanded speeds. A readout shall be displayed whenever the difference between the current speed and the commanded speed is greater than 40 knots. The readout shall be positioned above the speed dial, followed by its letter identifier, and shall be 60 percent of full size.

140 A

4.2.2.2 Altitude scale. The altitude scale (*Figure 15*) shall display the aircraft's current and commanded altitudes and the aircraft's vertical velocity. The altitude scale shall consist of a dial with an index, an altitude readout, a commanded altitude caret, commanded altitude readouts, and a vertical velocity arc. The commanded altitude caret shall be displayed whenever the aircraft's altitude is within 400 ft of the commanded altitude, and the vertical velocity arc is displayed whenever the CDM is limited. The altitude dial shall be positioned at the RHRP.



a. Current and commanded altitudes and vertical velocity arc displayed; CDM limited.

b. Current altitude and commanded altitude caret displayed.

FIGURE 15. Altitude scale.

4.2.2.2.1 Altitude dial. The altitude dial (*Figure 16*) shall consist of 10 bold dots equally spaced around a 25-mr circle and a 10.5-mr index located 12.5 mr from the center of the dial. The index shall make one complete clockwise revolution for every 1000 feet of increased altitude. The center of the dial shall be located at the RHRP.

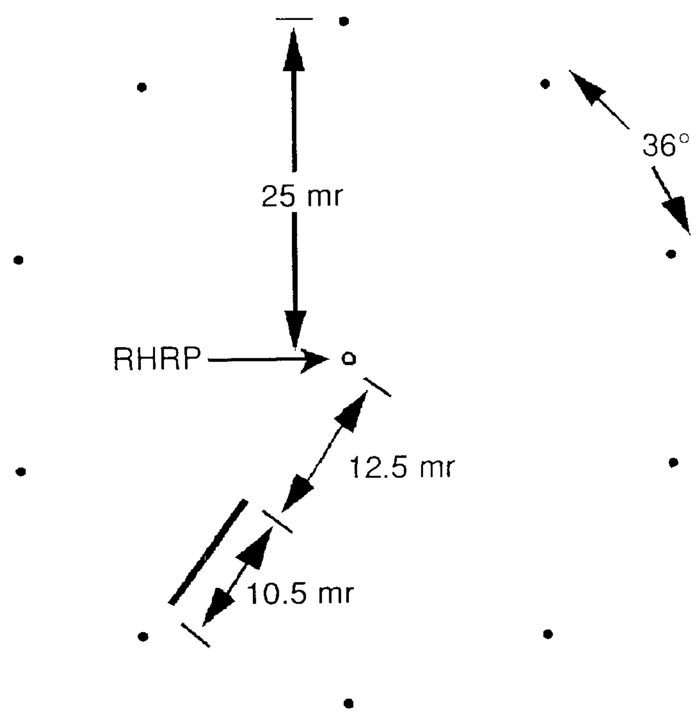


FIGURE 16. Altitude dial.

4.2.2.2.2 Altitude readout. The altitude readout, composed of five digits, shall be displayed at the center of the altitude dial. Whenever the aircraft's altitude is greater than or equal to 10,000 ft, the two leading digits (thousands) shall be displayed full size (7 mr high by 4 mr wide) and the remaining three digits (hundreds, tens and units) shall be displayed at 60 percent of full size. The resolution of the display shall be to the nearest hundred feet.

10000

When the aircraft's altitude is less than 10,000 ft, all the digits shall be displayed full size. Leading zeroes shall be displayed as blank spaces. The resolution of the display shall be to the nearest ten feet.

9870

4.2.2.2.3 Commanded altitude caret. The commanded altitude caret (*Figure 17*) shall point to the commanded altitude whenever the difference between the current altitude and the commanded altitude is less than 400 feet. The caret shall be located on the outside edge of the altitude dial pointing inward.

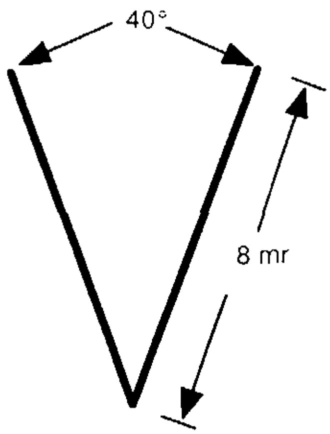


FIGURE 17. Commanded altitude caret.

4.2.2.2.4 Commanded altitude readouts. The commanded altitude readouts shall display the various commanded altitudes. A readout shall be displayed whenever the difference between the current altitude and a commanded altitude is greater than 400 feet. The readouts shall be positioned above the altitude dial.

All digits shall be 60 percent of full size with leading zeros displayed as blank spaces. The resolution of the display shall be to the nearest foot. The last readout shall be positioned 40 mr above and 10 mr left of the RHRP. Preceding readouts shall be positioned at 10-mr increments above their following readouts.

1500 S
600 D

4.2.2.2.5 Vertical velocity arc. The vertical velocity arc (*Figure 18*) shall display the aircraft's vertical velocity when read against the altitude dial. The vertical velocity arc shall be a bold arc that is displayed whenever the CDM is limited. During a climb, the amount of vertical velocity shall be displayed by a bold arc that starts at the 9 o'clock position (750 ft) and extends in the clockwise direction along the upper arc of the altitude dial. During a dive, it shall extend in the counter-clockwise direction along the lower arc.

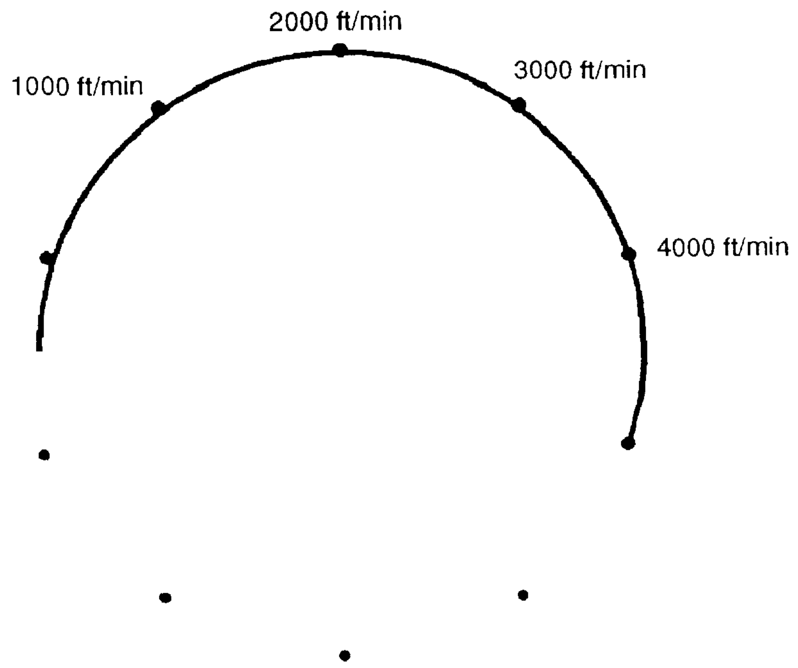


FIGURE 18. Vertical velocity arc.

In addition to the vertical velocity trend information, it is recommended that a digital readout of vertical velocity also be presented just below the altitude scale.

VV–1500

4.2.2.3 Heading scale. The heading scale (*Figure 19*) shall indicate the aircraft's magnetic heading and shall consist of a horizontal scale and a lubber line. The lubber line shall indicate the aircraft's magnetic heading when read against the horizontal scale. The center point of the heading scale shall be located above the midpoint of a line connecting the LHRP and RHRP.

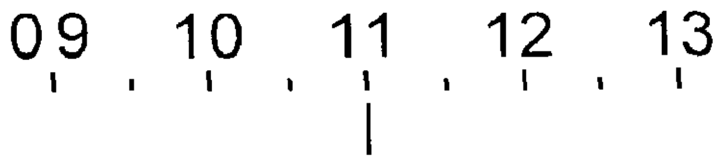


FIGURE 19. Heading scale.

4.2.2.3.1 Horizontal heading scale. The horizontal heading scale (*Figure 20*) shall be a continuous scale that moves left and right indicating aircraft heading when read against fixed lubber line. The scale shall consist of 5-mr, vertical tic marks every 10 degrees and 3-mr, vertical tic marks every 5 degrees. A minimum of 30 degrees shall be displayed and the scale compressed at a 5:1 ratio. Two-digit numeric labels that range from 01 to 36 shall be positioned above the 10-degree tic marks indicating 10 to 360 degrees of heading.

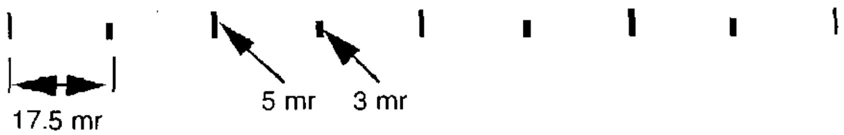


FIGURE 20. Horizontal heading scale.

4.2.2.4 Bank scale. The bank scale (*Figure 21*) shall display the aircraft's bank and sideslip. The bank scale shall consist of a curved bank scale drawn around the CTFOV and a bank/sideslip pointer.

FIGURE 21. Bank scale with 20° right bank.

4.2.2.4.1 Curved bank scale. The curved bank scale (*Figure 22*) shall consist of a center index and three tic marks at 10-degree intervals on either side of the index representing 10, 20, and 30 degrees of aircraft bank. When the aircraft's bank angle is greater than 25 degrees, additional tic marks shall be displayed at the 45-degree and 60-degree positions on the same side of the scale as the bank/sideslip pointer. Likewise, when the bank angle is greater than 55 degrees, additional tic marks shall be drawn at the 90-degree and 135-degree positions.

The radius of the bank scale shall be centered about the CTFOV. If the CDM comes within 20 mr of the zero bank index, the bank scale shall be lowered to maintain the 20-mr separation between the CDM and the scale.

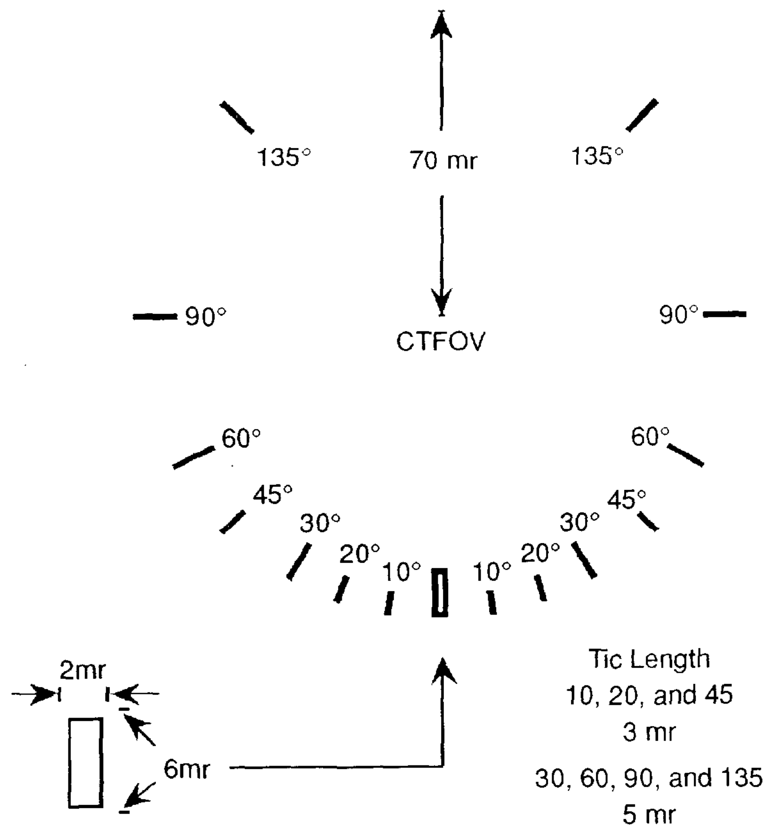


FIGURE 22. Curved bank scale.

4.2.2.4.2 Bank/sideslip pointer. The bank/sideslip pointer (*Figure 23*) shall be divided into two sections: a triangle shaped upper section and a trapezoid shaped lower section. The upper section shall indicate the magnitude and direction of roll when read against the curved bank scale. The lower section shall indicate the magnitude and direction of aircraft sideslip when read against the upper section.

When the aircraft is at wings-level flight, the bank/sideslip pointer shall be positioned below the center index of the curved bank scale with the tip of the pointer touching the bottom of the center index of the scale. As the aircraft banks in the clockwise direction (right wing down), the pointer shall move an equal number of degrees around the curved scale in the counter-clockwise direction; likewise for a left wing down bank. The pointer has unlimited 360-also suggest degree movement about the CTFOV and is rotated for all bank angles to point toward the CTFOV.

The lower section shall be positioned relative to the upper section by the amount of sideslip. For example, with 30 degrees of right bank and a sideslip of 3 degrees to the right, the upper section is rotated to the 30-degree tic and the lower section is rotated 33 degrees.

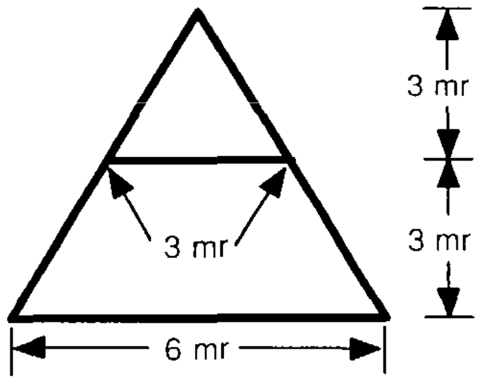


FIGURE 23. Bank/sideslip pointer.

4.2.3 Navigational symbology. The navigational symbology shall provide the pilot with location and steering information to return to a designated flight path or course. The symbology shall consist of a course deviation indicator (CDI), a vertical deviation indicator (VDI), flight director steering bars, and a tactical air navigation (TACAN) indicator. The CDI, VDI, and steering bars shall be positioned relative to the CDM. The TACAN indicator shall be positioned relative to the CTFOV.

4.2.3.1 Course deviation indicator (CDI). The course deviation indicator (*Figure 24*) shall display the selected course and the magnitude and direction of deviation. The indicator shall be centered around the CDM and shall consist of a scale and a pointer. A numerical readout of the selected course should be provided on the display.

The scale shall consist of four dots with a maximum of 2 dots being displayed at any one time. The pointer shall be read against the CDM and CDI scale. The pointer and scale shall rotate about the CDM to indicate the selected course.

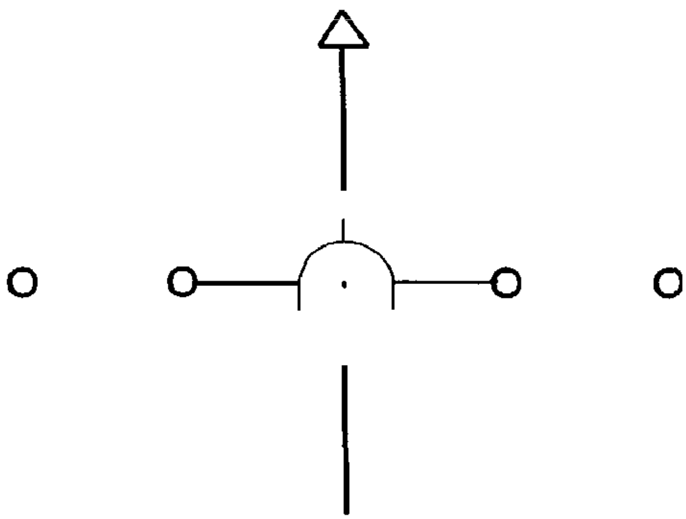


FIGURE 24. Course deviation indicator.

4.2.3.1.1 CDI scale. The CDI scale (*Figure 25*) shall contain four 3-mr circles, or dots, with a maximum of two dots being displayed at any instance. On either side of the scale, the inner two dots shall be located 15 mr from the center and each outer dot located another 15 mr from the inner dot. The CDI scale shall be centered upon the CDM and shall be free to rotate a full 360 degrees about the CDM.

When the deviation is more than one and one–half dots, two dots shall be shown on the same side of the CDM as the CDI pointer. When the deviation is between one–half and one and one–half dots, the inner two dots on each side of the CDM shall be shown. No dots shall be shown when the deviation is less than one–half dot.

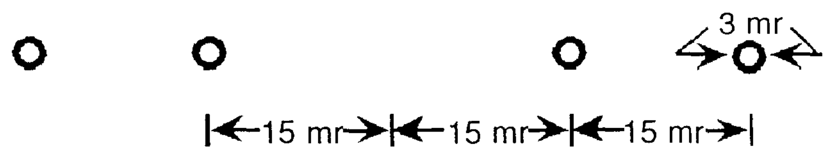


FIGURE 25. CDI scale.

4.2.3.1.2 CDI pointer. The CDI pointer (*Figure 26*) shall indicate course deviation when read against the *CDI scale*.

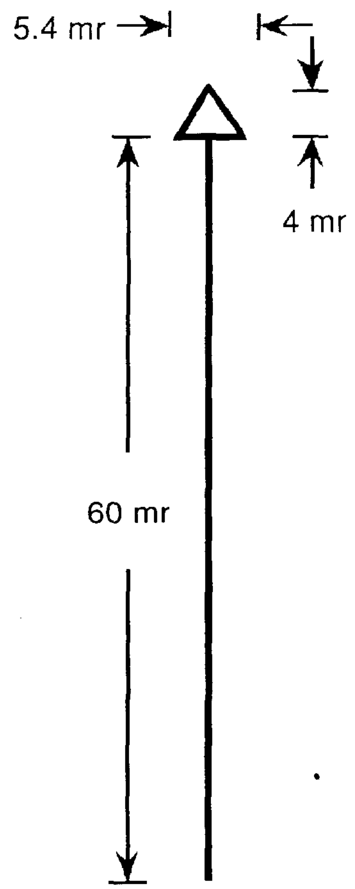


FIGURE 26. CDI pointer.

4.2.3.2 **Vertical deviation indicator (VDI).** The Vertical Deviation Indicator (VDI) (*Figure 27*) shall display the magnitude and direction of the aircraft's vertical deviation from the desired glidepath.

The indicator shall consist of a scale and a pointer. The pointer shall be read against the scale. For ILS glideslope, one dot of pointer deflection represents 0.35 degrees of glideslope deviation.

The VDI shall be located to the right of the CDM and shall move vertically with it.

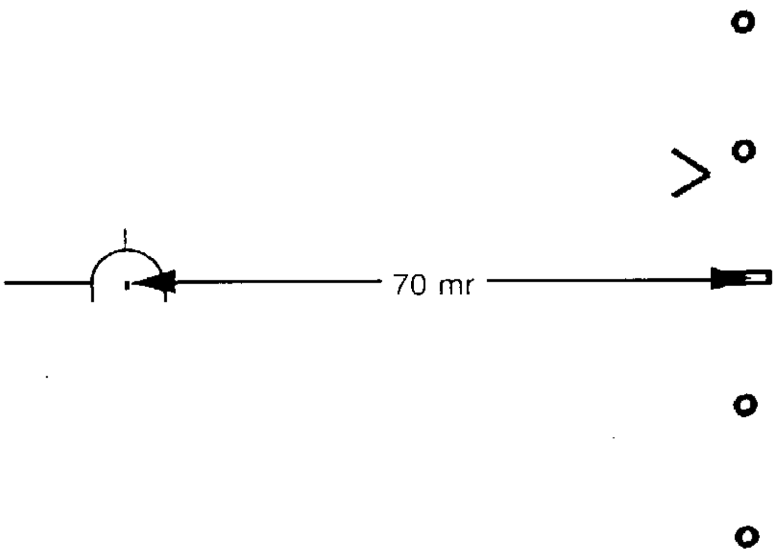


FIGURE 27. Vertical deviation indicator.

4.2.3.2.1 VDI scale. The VDI scale (*Figure 28*) shall be used in conjunction with the VDI pointer to indicate vertical deviation. The scale shall consist of four 3-mr circles, or dots, and a 6-mr by 2-mr, open–centered box. The dots shall be located two above and two below the box.

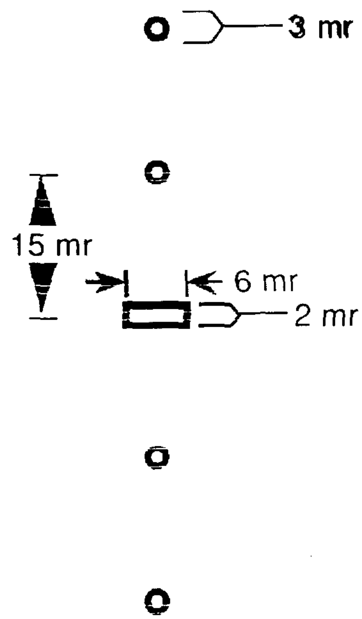


FIGURE 28. VDI scale.

4.2.3.2.2 VDI pointer. The vertical deviation pointer (*Figure 29*) shall indicate vertical deviation when read against the VDI scale. The pointer shall be located on the left side of the VDI scale pointing to the right.

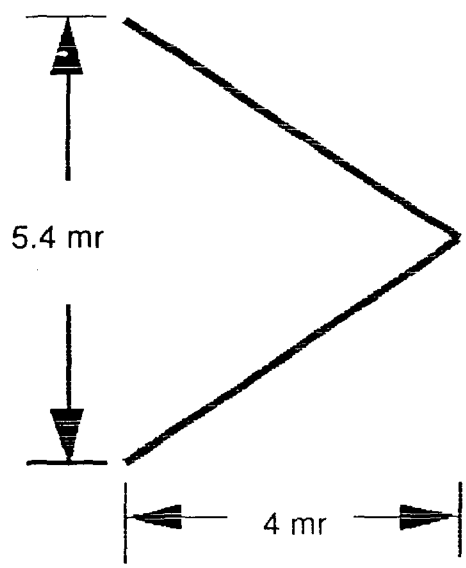


FIGURE 29. VDI pointer.

4.2.3.3 Flight director steering bars. The two flight director steering bars, bank steering and pitch steering (*Figure 30*), shall indicate the amount and direction of the flight director roll and pitch steering error, respectively, when read against the CDM. As the pilot rolls and pitches in the direction of the bars, the steering errors decrease and the bars move toward the CDM. The aircraft is at the commanded roll and pitch angles when the bars are positioned on the CDM. Both bars shall be 80 mr in length and displayed whenever the HUD is in ILS mode. The movement of the bars shall be limited to 2.5 degrees.

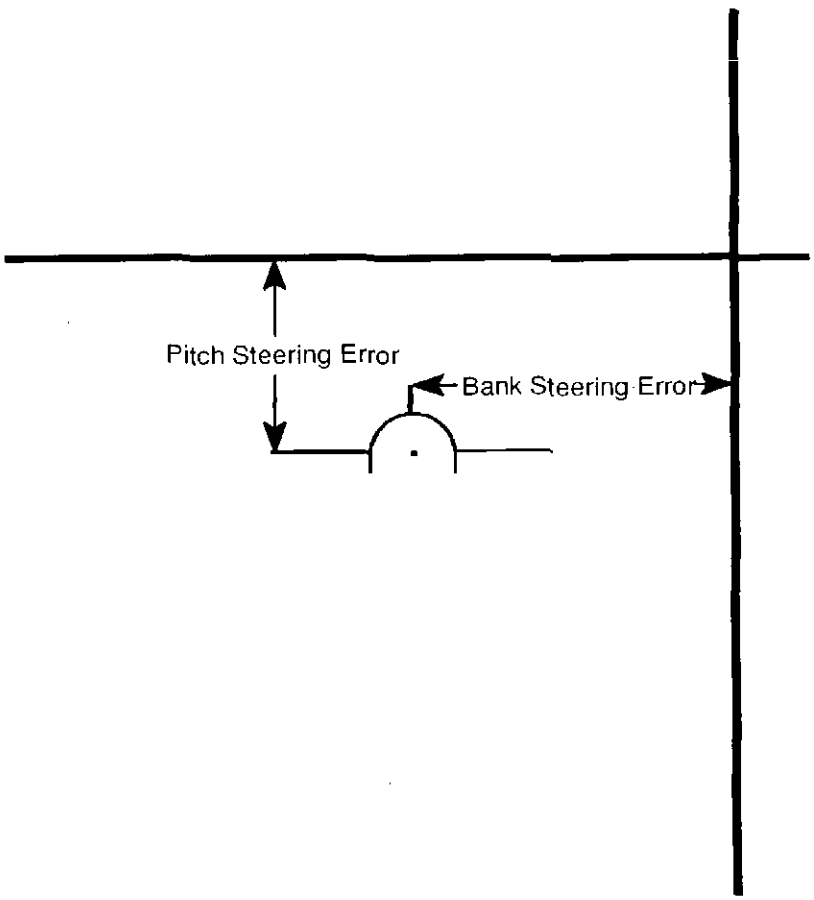


FIGURE 30. Flight director steering bars.

4.2.3.4 Bearing (VOR/waypoint) indicator. The bearing indicator (*Figure 31*) shall display the relative bearing to the selected navaid station and the radial from the station. The indicator shall consist of a bearing pointer, reference wings, and a readout. The pointer shall move about the center of the indicator to show the relative, magnetic bearing to the navaid station. The readout shall display the magnetic radial from the station. The pointer shall be removed and the readout shall display XXX whenever the navaid receiver is not receiving a signal.

The indicator shall be displayed in TACAN and ILS modes and shall be located in the upper right corner of the IFOV.

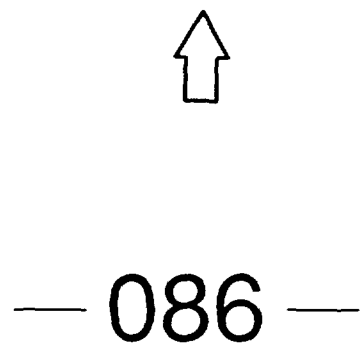


FIGURE 31. Bearing indicator.

4.2.3.4.1 Bearing pointer. The bearing pointer (*Figure 32*) displays the relative bearing to the selected navaid station. The pointer shall be located 20 mr from the center of the bearing indicator and shall be free to rotate a full 360 degrees about the center. If the navaid receiver is not receiving a signal from a station, then the pointer shall not display.

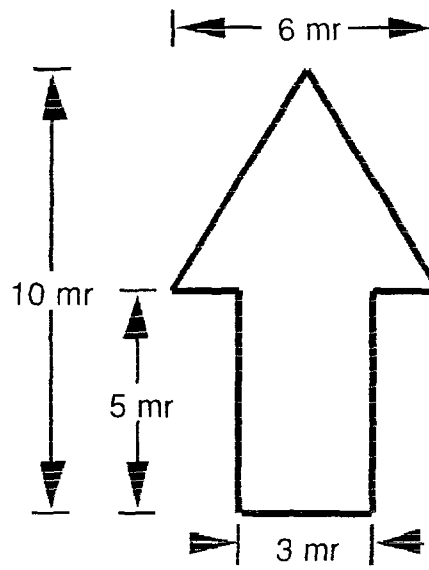


FIGURE 32. Bearing pointer.

4.2.3.4.2 Reference wings. The bearing pointer reference wings (*Figure 33*) display a reference point against which the bearing pointer can be read. The wings shall consist of two 8-mr horizontal bars that represent the aircraft's wings. The bars shall be located 10 mr from the center of the indicator.

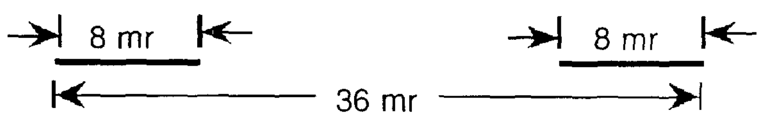


FIGURE 33. Reference tics.

4.2.3.4.3 Radial readout. The radial readout shall display magnetic radial from the selected navaid to the nearest degree. The readout shall consist of a 3-digit number, full size, with the leading zero shown. The readout shall display XXX whenever the navaid is not receiving a signal. The readout shall be located at the center of the bearing indicator.

086 or XXX

4.2.4 Mission symbology

4.2.4.1 Acquisition cursor, air-to-air (A/A). This vertical situation display (VSD) symbol shall be displayed in all search modes to enable manual target designation. The dimensions of the A/A cursor shall be scaled to the target symbol size (*Figure 34*).

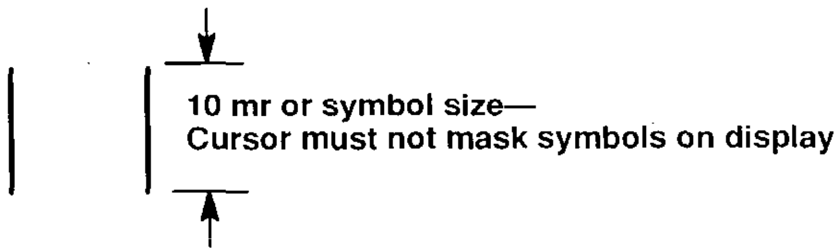


FIGURE 34. Acquisition cursor A/A.

4.2.4.2 Acquisition cursor, air-to-ground (A/G) B-scope. This head down symbol shall be displayed with a B-scope presentation to indicate IP or target location in range and azimuth (*Figure 35*).

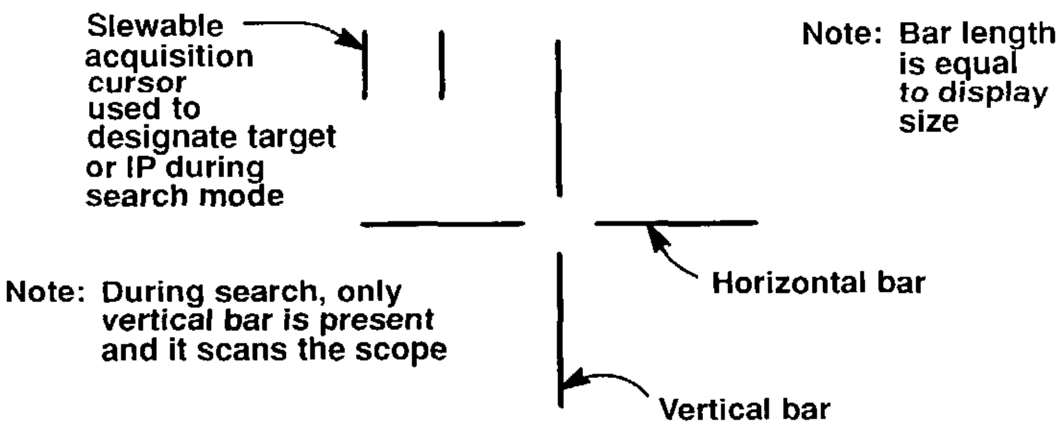


FIGURE 35. Acquisition cursor, A/G B-scope.

4.2.4.3 Acquisition cursor, A/G PPI-scope. This head down symbol shall be displayed with a plan position indicator(PPI) scope presentation to indicate IP or target location in range and azimuth (*Figure 36*).

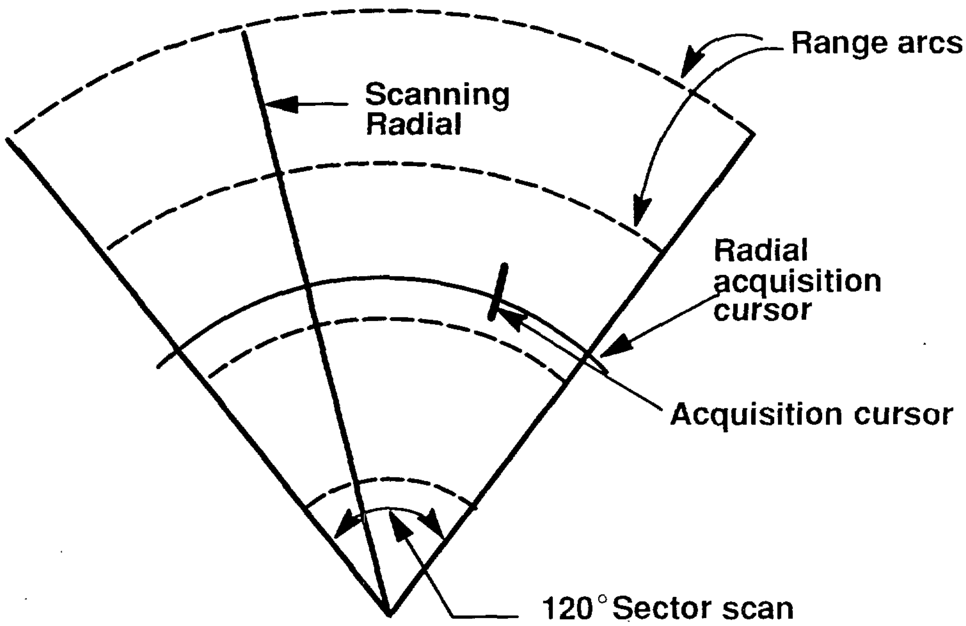


FIGURE 36. Acquisition cursor, A/G PPI-scope.

4.2.4.4 Aiming reticle, stadiametric. This symbol shall be used for stadiametric ranging. It shall be a variable diameter circle surrounding a _____-mr diameter circle and _____-mr diameter pipper dot (*Figure 37*).

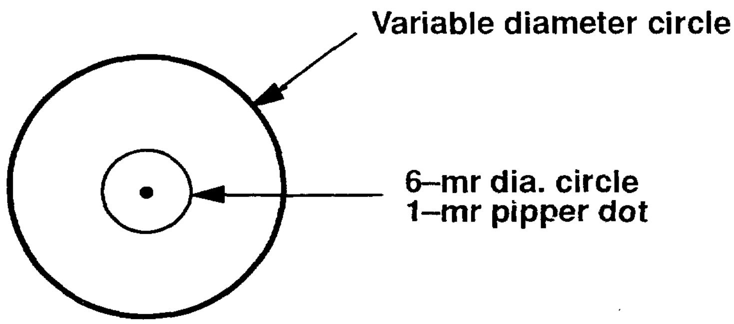


FIGURE 37. Aiming reticle, stadiametric.

4.2.4.5 Aiming reticle, standby. This symbol shall be used for manual weapons delivery missions. It shall have ________ diameter and ________ diameter dashed octagons centered around a ________ pipper dot (*Figure 38*).

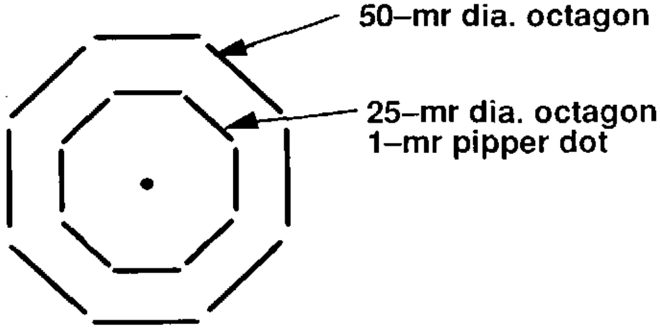


FIGURE 38. Aiming reticle, standby.

4.2.4.6 Allowable steering error (ASE) circle and steering dot for A/A attack. The ASE circle and the steering dot shall be used as A/A radar display features designed to provide either lead angle collision or pursuit steering depending on the phase of an attack. The circle shall vary in size with respect to target range and target aspect angle (TAA) (*Figure 39*).

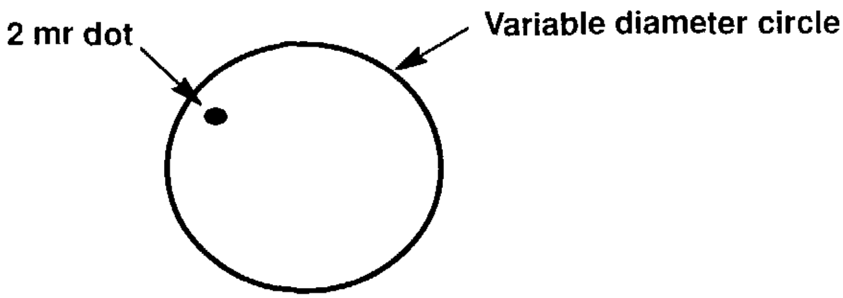


FIGURE 39. Allowable steering error (ASE) circle and steering dot (A/A attack).

4.2.4.7 Antenna azimuth and elevation markers. These carets shall indicate the current radar scan positions on a VSD. At lock-on, they shall indicate the azimuth and elevation angles of the target when read against scales (see *Figure 49*) on the edge of the display. Tick marks shall be every _______ degrees, and numerics, every _____ tick mark. (*Figure 40*)

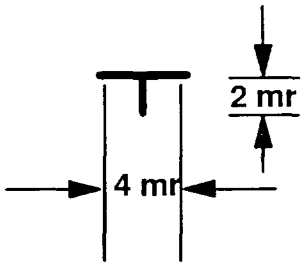


FIGURE 40. Antenna azimuth and elevation marker.

4.2.4.8 Azimuth steering line (ASL). This symbol shall be displayed relative to the heading scale and shall provide a steering reference with respect to the FPM. The ASL shall be resolved vertically in the ground axes with respect to the ground stabilized reference point (for example, target or steerpoint) *(Figure 41)*.

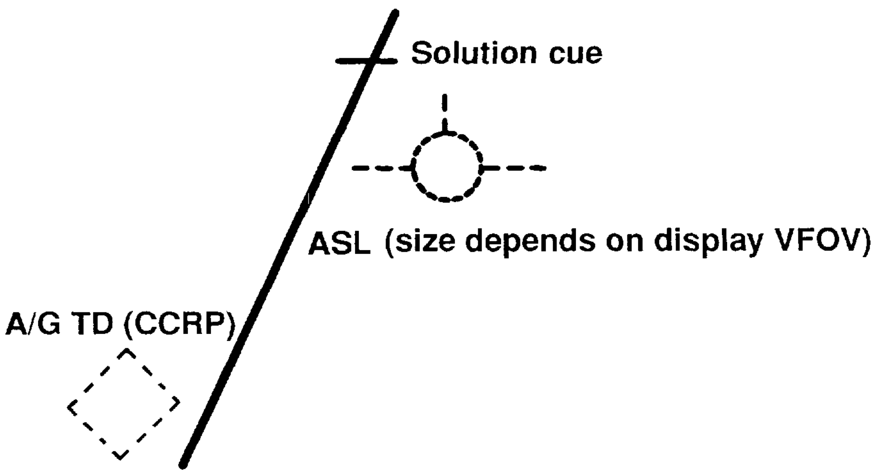


FIGURE 41. Azimuth steering line (ASL).

4.2.4.9 Beacon symbol (steerpoint symbol, destination symbol, initial point (IP) symbol). This symbol is displayed on the head-down and head-up displays. This symbol shall be used for navigation, fixtaking, weapon delivery, and tanker rendezvous to display the range and bearing of steerpoints or coded beacon replies from ground-based or airborne beacons (*Figure 42*).

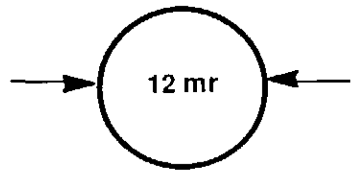


FIGURE 42. Beacon symbol (steerpoint symbol, destination symbol, initial point symbol).

4.2.4.10 Bombfall line (BFL). The bombfall line shall extend between the FPM and aiming pipper (impact point) and shall approximate the trajectory that the weapon assumes to the target (*Figure 43*).

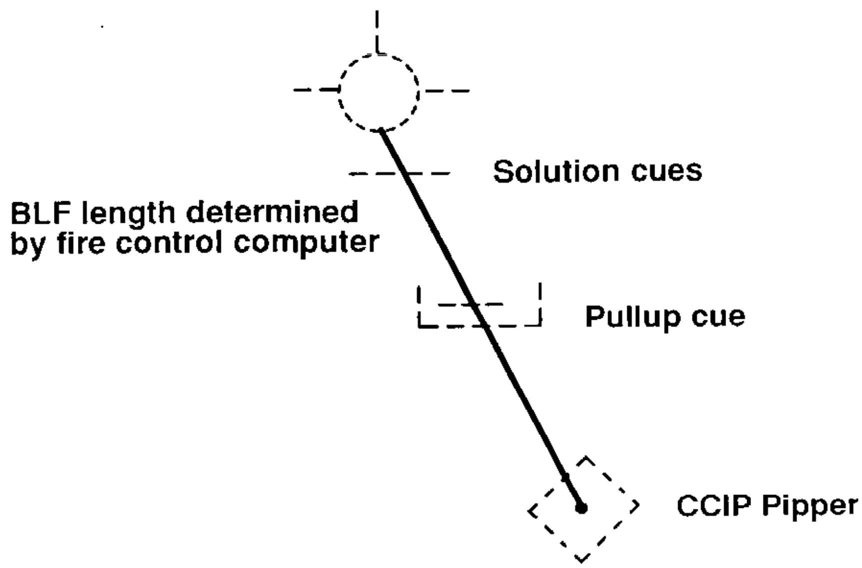


FIGURE 43. Bombfall line (BFL).

4.2.4.11 Breakaway symbol. This symbol shall be displayed at minimum weapon release range and/or upon reaching the minimum safe pull-out altitude during A/G weapon delivery. This symbol shall flash at 5 Hz when necessary to indicate a need for immediate pull-up of the aircraft (*Figure 44*).

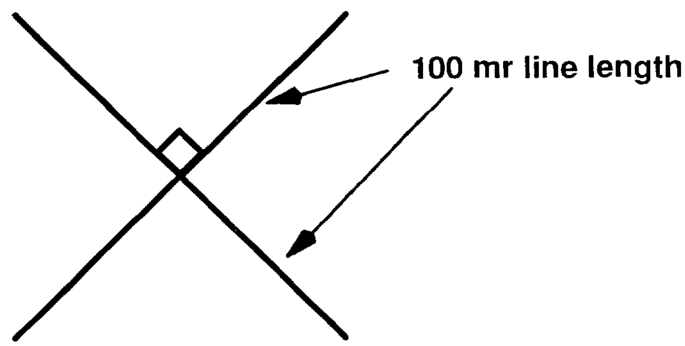


FIGURE 44. Breakaway symbol.

4.2.4.12 Continuously computed impact line (CCIL). This symbol shall be used to display a range of simulated bullet points associated with flight conditions during snapshoot gunnery solutions. Bullet time-of-flight (TOF) points shall be marked by tick intervals on the CCIL at _____, _____ and _____ seconds TOF (*Figure 45*).

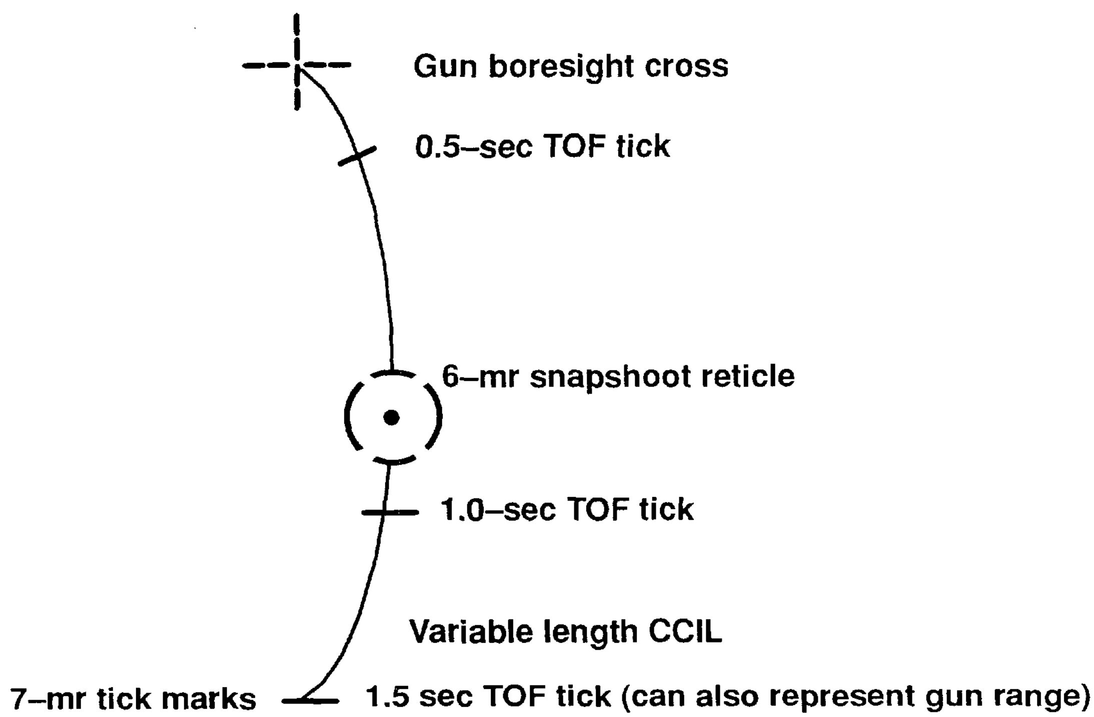


FIGURE 45. Continuously computed impact line (CCIL).

4.2.4.13 Gun cross. This symbol shall be used for gun target tracking on HUDs to indicate the projectile conversion point (with no corrections) on the aircraft boresight axis or the projectile position at some distance corresponding to a normal firing range (for A/G dedicated aircraft). A reticle similar to this cross is used in forward looking infrared (FLIR) and radar presentations to represent field of view (FOV) center or a cursor (*Figure 46*).

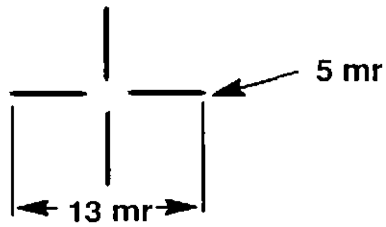


FIGURE 46. Gun cross.

4.2.4.14 Lead computing optical sight (LCOS) track line. This line shall provide an azimuth tracking reference joining the gun boresight cross with the A/A aiming reticle. The LCOS lag line symbol shall indicate the degree of pipper unsettlement (lag), if any, and the direction the pipper is moving for a settled solution (*Figure 47*).

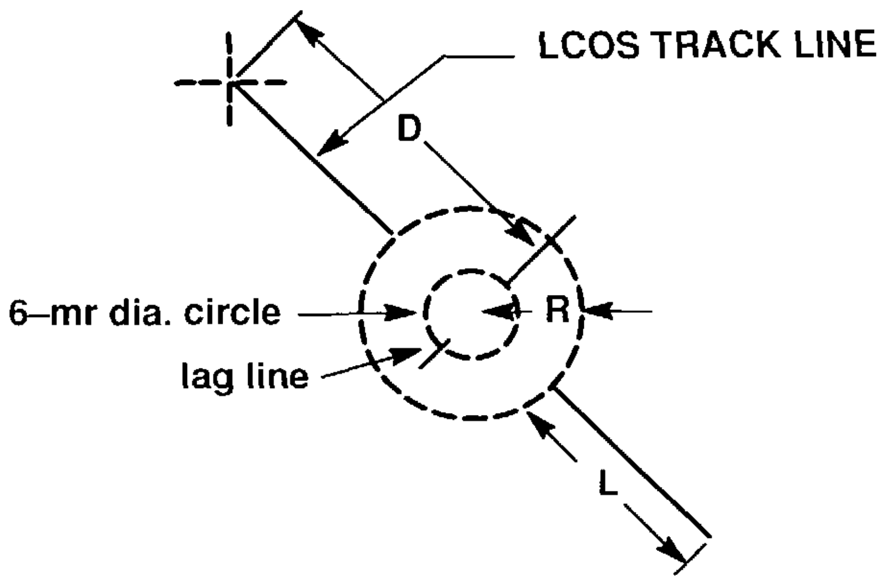


FIGURE 47. Lead computing optical sight (LCOS) track line and lag line.

4.2.4.15 *Pull-up anticipation cue.* The symbol shall indicate an approaching pull-up requirement in A/G modes. The roll stabilized symbol shall be caged in azimuth and referenced to the FPM (*Figure 48*).

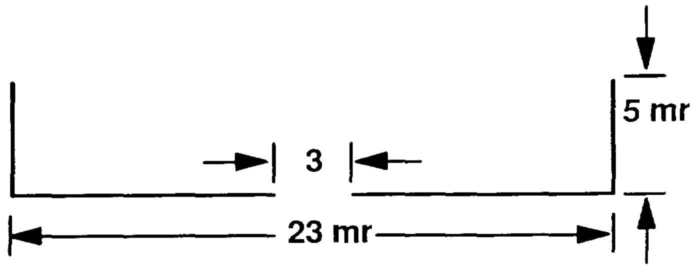


FIGURE 48. Pull-up anticipation cue.

4.2.4.16 Radar range scale. This fixed scale shall be displayed after lock-on occurs. The moving caret shall indicate target range. See *4.3.1* for a description of Rmax 1, Rmax 2, and Rmin (*Figure 49*).

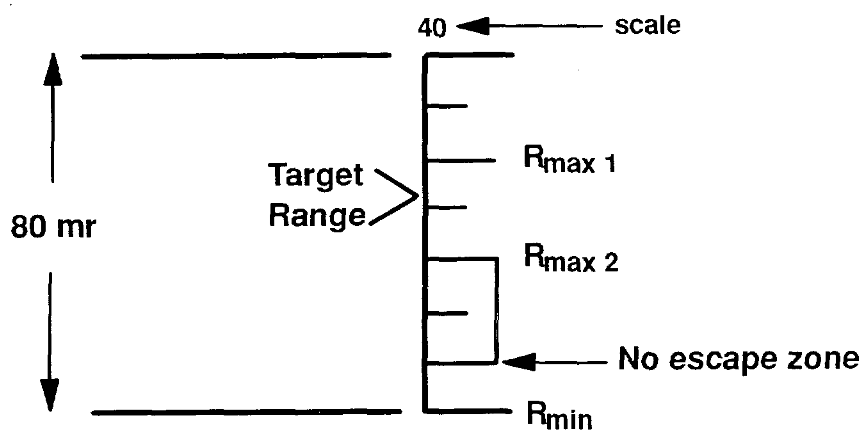


FIGURE 49. Radar range scale.

4.2.4.17 Solution cues, air-to-ground (A/G). These symbols shall indicate when a computed level release or toss release solution is available for the weapon selected. They shall vary in position along the bombfall line with reference to the FPM. The first optimum weapon release cue shall represent the first or lower solution to the equation for the selected weapon. As a solution is approached, the cue shall move down the BFL. The second optimum weapon release cue shall represent the last or upper solution to the equation for the selected weapon and shall move in the same manner as the first *(Figure 50)*.

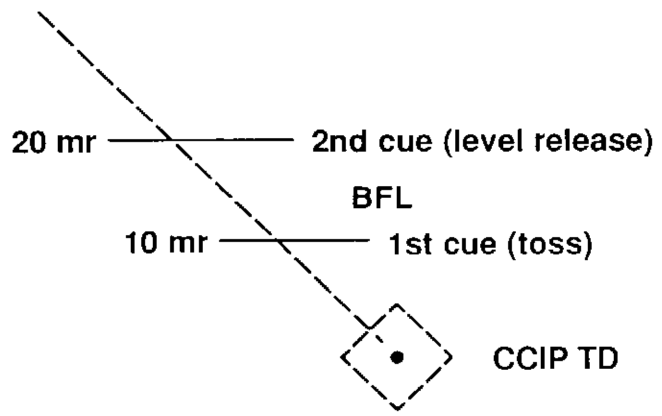


FIGURE 50. Solution cues (A/G).

4.2.4.18 Target designator (TD)/radar lock-on, air-to-air. This symbol shall be displayed when the radar is angle tracking a target to indicate the antenna line of sight to the target (*Figure 51*).

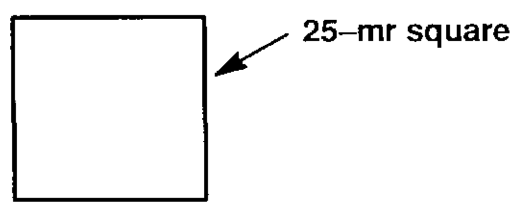


FIGURE 51. Target designator/radar lock-on.

4.2.4.19 Target designator, A/G continuously computed impact point (CCIP). This HUD symbol shall be attached to the BFL and shall represent the weapon impact point if the weapon is released at that point in time. CCIP placement shall be based on computer computations (*Figure 52*).

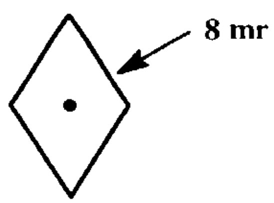


FIGURE 52. A/G CCIP TD.

4.2.4.20 Target designator, A/G continuously computed release point (CCRP). This HUD symbol shall display azimuth and elevation of a ground target or weapon impact point. It shall be slewable to permit corrections (*Figure 53*).

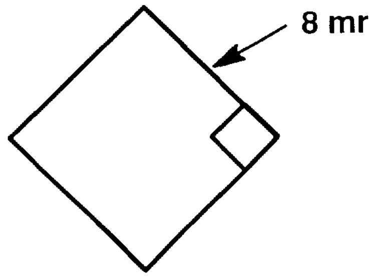


FIGURE 53. A/G CCRP TD.

4.2.4.21 Target locator line (A/A and A/G). This symbol shall indicate location of target inertial navigation coordinates or radar antenna look angle when target lock-on occurs at angles outside of the HUD total field of view (TFOV) (*Figure 54*).

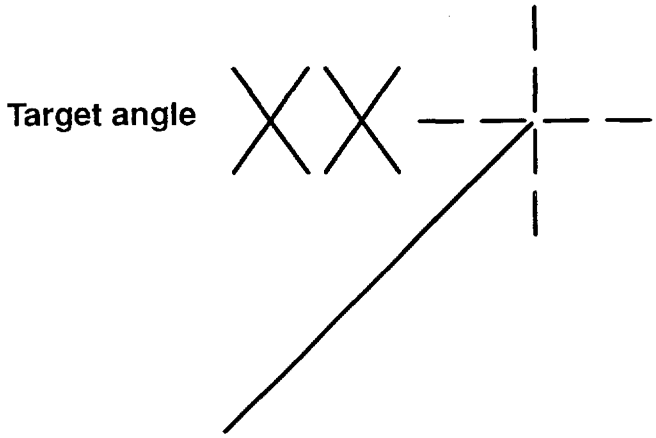


FIGURE 54. Target locator line.

4.2.4.22 Target identification set, laser (TISL) reticle. This symbol shall be displayed superimposed on the target when the TISL system is tracking a target. The TISL direction line shall be a dashed line connecting the TISL reticle to the aiming pipper to facilitate target azimuth alignment and tracking (*Figure 55*).

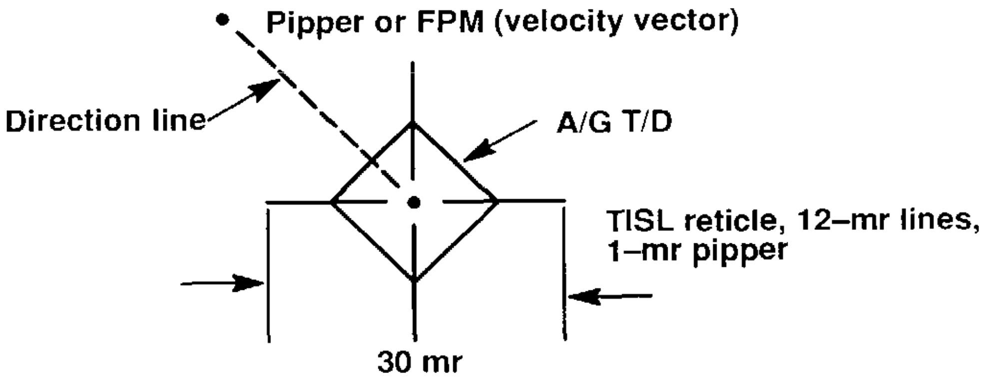


FIGURE 55. Target identification set, laser (TISL) reticle and direction line.

4.2.4.23 Terrain following (TF) cue. This symbol shall provide vertical TF steering cues. It shall be displayed relative to the FPM and is normally caged to the FPM azimuth (*Figure 56*).

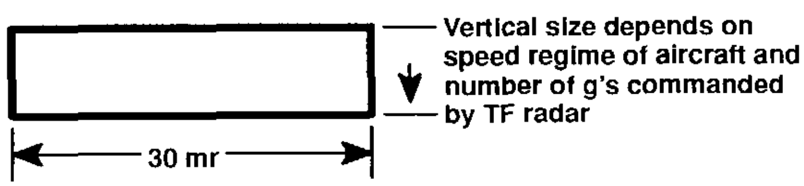


FIGURE 56. Terrain following cue.

4.3 Symbols and layouts. The symbols defined in section *4.3* shall be drawn using the symbols shown in figures accompanying each paragraph as guidance.

5.3 Symbols and layouts verification. All display symbology in section *4.3* shall be verified by visual inspection of the shape and dimensions of each symbol and alphanumeric character and a functional verification (hot bench test or flight test) of the operational characteristics of each symbol. New symbols proposed in lieu of those in section *4.3* must provide a justifiable improvement in system capability and must be functionally verified.

4.3.1 Aiming reticle, air to air. This symbol shall be displayed during air-to-air (A/A) combat modes to aid in visual target acquisition. Subparagraphs *4.3.1.a* through *4.3.1.k* contain the standard symbols which shall be used with the reticle to display target and weapon parameters to the pilot. (*Figures 57a* through *57k*.)

a. Analog closure rate caret. This symbol shall be displayed around the inside perimeter of the aiming reticle. It shall be scaled to _____ per clock position with positive and negative rates limited at 5 o'clock (______) and 7 o'clock (_______), respectively (*Figure 57a*).

b. Circular analog target range bar. This symbol shall display range to target and shall be scaled to _____ or _____ per clock position (*Figure 57b*).

c. Range indices. Tick marks shall be used on the reticle to denote a clock position (*Figure 57c*).

d. In-range markers. These symbols shall be used to display minimum and maximum target ranges suitable for the weapon selected (*Figure 57d*).

e. R_{max} 1 reference tick. The R_{max} 1 symbol shall denote the maximum launch range computed from the aerodynamic range of the weapon selected against a nonmaneuvering target (*Figure 57e*).

f. R_{max} 2 reference tick. The R_{max} 2 range symbol shall be computed for a target evasive maneuver at the terminal phase of missile flight (*Figure 57f*).

g. R_{min} reference tick. The R_{min} range symbol shall be computed from the minimum time of flight required for missile guidance and arming (*Figure 57g*).

h. Pipper, A/A. This _____ diameter dot shall be used in all A/A modes except missile, where it is usually replaced by a missile seeker head circle or diamond at missile boresight. Pipper position depends on radar computations of target aircraft range (*Figure 57h*).

i. Range at bullet one second TOF. This tick mark shall denote bullet range at one second TOF or maximum gun range (*Figure 57i*).

j. Snapshoot reticle. The A/A snapshoot reticle shall be depicted as a ______ diameter circle. The reticle is positioned on the CCIL at target range (*Figure 57j*).

k. Target aspect angle (TAA). TAA shall depict the target velocity vector direction such that 12 o'clock denotes 180–degree difference between aircraft and target velocity vector, 6 o'clock denotes zero difference and 9 o'clock denotes the target is passing left to right in front of aircraft nose (*Figure 57k*).

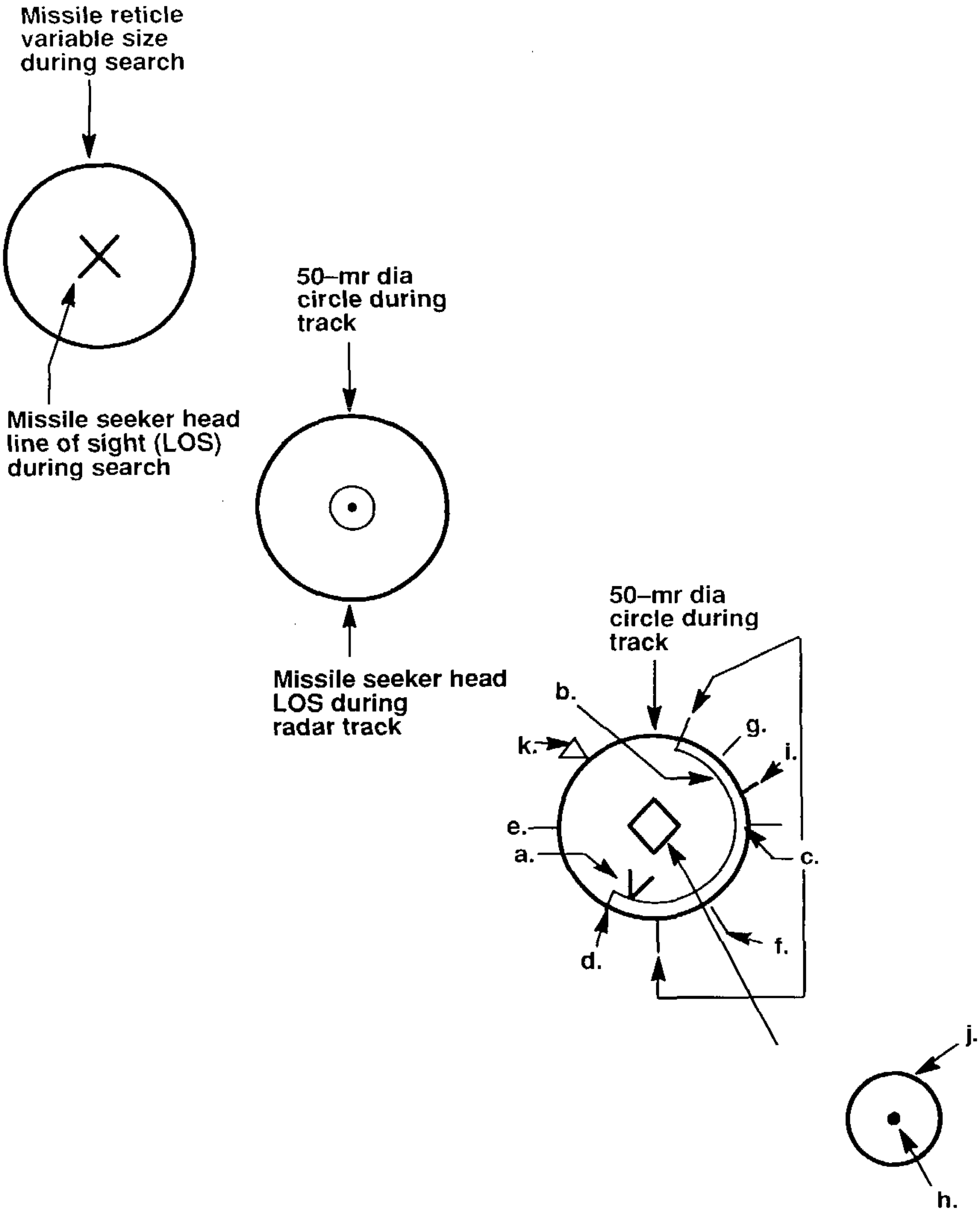


FIGURE 57. Aiming reticle, air-to-air (A/A).

4.3.2 **Aiming reticle, air-to-ground (A/G).** This _____-mr diamond reticle shall be displayed during air-to-ground weapon delivery modes to enable target acquisition. It shall be centered on the pipper. Subparagraphs *4.3.2.a* through *4.3.2.c* contain the standard symbols which shall be used with the reticle to display target and weapon parameters to the pilot (*Figure 58*).

a. Target in-range bar. The range bar appears when the target is in range for the weapon selected (*Figure 58a*).

b. Pipper, A/G. This ______ diameter dot is used in all A/G modes (*Figure 58b*). Pipper position depends on A/G mode selected. It is positioned in azimuth to one of the following points, depending on the weapon delivery mode selected:

(1) To the flight path marker (FPM)

(2) To the weapon impact point (CCIP)

(3) To the HUD depression angle (manual setting)

(4) To the weapon boresight, e.g., electro-optical weapon

(5) To the IR weapon seeker head position.

c. Reticle eyebrows. The eyebrows are two short vertical lines centered above the pipper at _____ and _____. They appear only when the reticle is depressed _____ or more (*Figure 58c*).

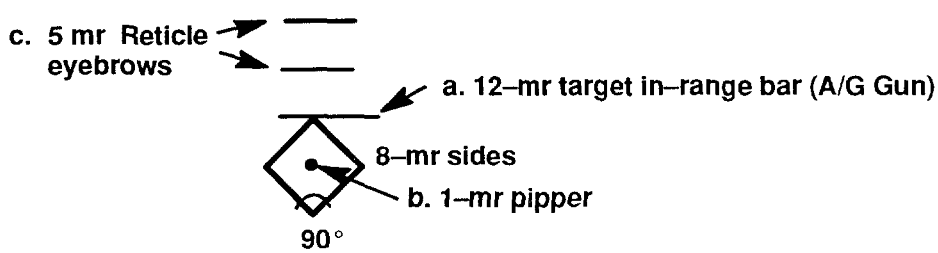


FIGURE 58. Aiming reticle, air-to-ground.

4.3.3 Character fonts. The following types of character fonts, as applicable, shall be used on weapon system displays requiring alphanumeric information. See *AFGS–87213* for the recommended character sizes for each type of font.

a. Dot matrix font. The font used for dot matrix displays shall comply with the following design criteria (*Figure 59a*):

(1) The font shall be as similar to the raster-generated font (*4.3.3.b*) as possible so that character style can be standardized across electronic displays in the cockpit.

(2) Horizontal and vertical segments or strokes making up each character shall be at least two pixels wide to reduce confusion of one character with another in the event of a single row or column failure.

(3) Character height shall conform with the criteria in *AFGS–87213*.

(4) *Character stroke width shall conform with the criteria in AFGS–87213* except that stroke width (SW) shall be greater than 0.12 h and less than 0.22 h, where h is character height.

An example of a dot matrix font for aircraft cockpit displays is shown in *Figure 59a*. The 7 x 9 matrix size shown is the minimum matrix size suitable for use in aircraft cockpit displays. If display size, resolution, and information density permit, larger matrix sizes with two pixel stroke widths are recommended.

Any proposed font shall be subject to procuring activity approval.

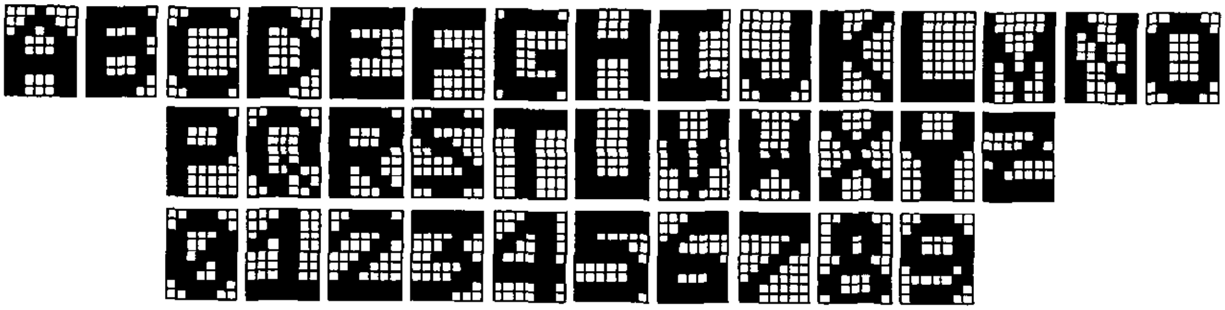


FIGURE 59. a. Dot matrix font.

b. Raster-generated font. The raster-generated character font shall be used for weapon system displays requiring raster-generated characters. An example of a raster–generated font for aircraft cockpit displays is shown in *Figure 59b.* Any proposed font shall be subject to procuring activity approval.

FIGURE 59. b. Raster-generated font.

c. Stroke-written font. This font is the recommended stroke-written character font for weapon system displays requiring stroke-written characters. Size of font should be scaled in accordance with display resolution requirements. The slash through the zero is optional where context makes it obvious that it is not the alphabetic character "O." Any proposed font shall be subject to Air Force approval (*Figure 59c*).

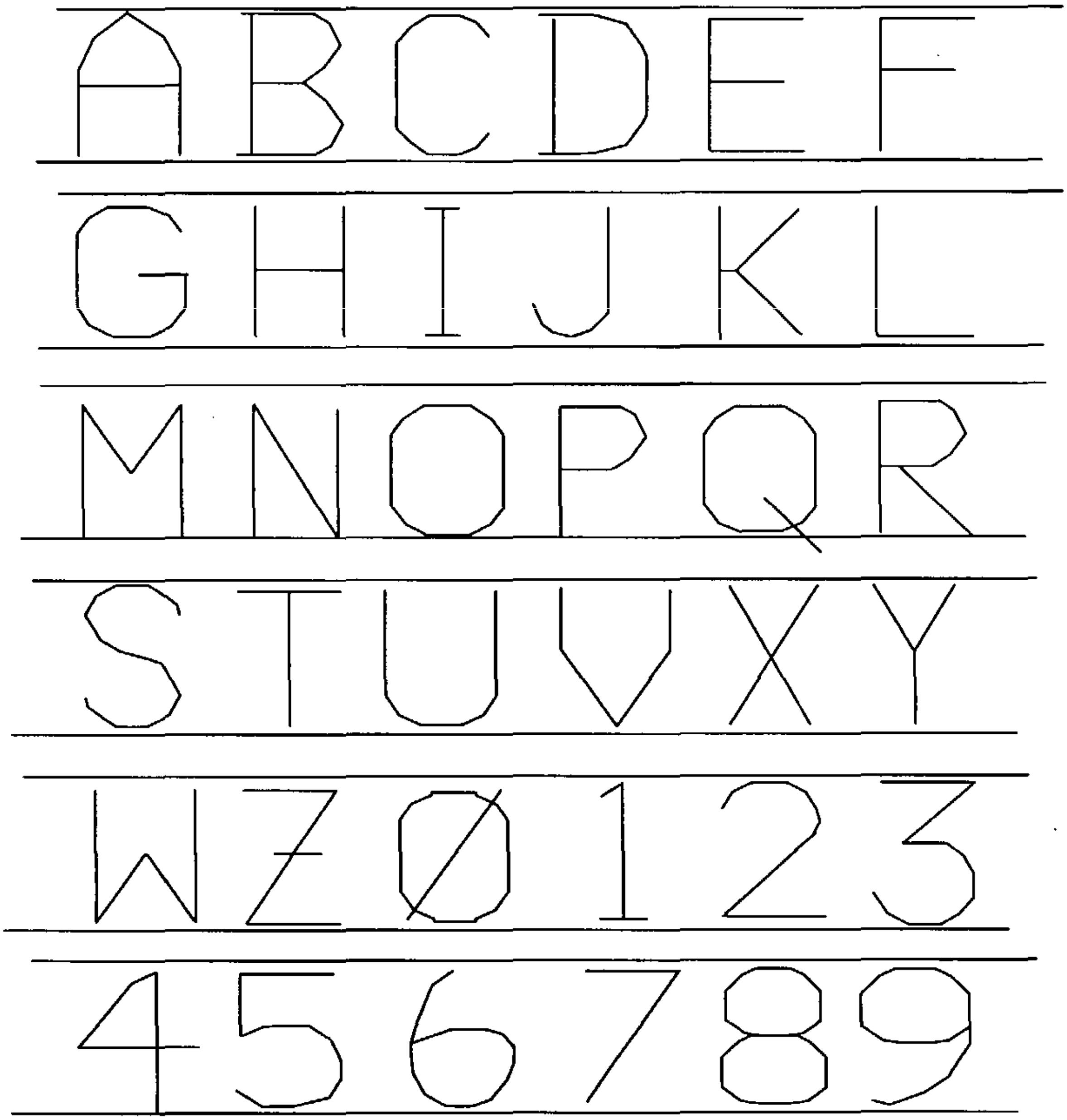


FIGURE 59. c. Stroke-written font.

4.3.4 Horizontal situation display (HSD). The HSD shall present essential moving map and data frame information to be utilized for flight and combat application. The information presented depends on the requirements of the different modes of operation. *Table I* is a matrix of suggested information requirements and associated symbology for each mode (*Figure 60*).

TABLE I. HSD mode information matrix.

Information Requirements	MODE Take Off	 Nav	 Tf/ Ta	 Weapon Del	 Ldg	Figure
Map	X	X	X	X	X	60b
Aircraft Position	X	X	X	X	X	60a
Heading	X	X	X	X	X	60a
Ground Track	X	X	X	X	X	60a
Nav Steer	X	X			X	60a
To/From	X	X			X	60a
Target Points/JTIDS		X	X	X		60a
Target Designator		X	X	X		60a
Fuel Range	X*	X*	X*	X*	X*	60a
Data Frame	X	X	X	X	X	60a
Fuel Range Circle	X*	X*	X*	X*	X*	60a
Time	X	X	X	X	X	60a

NOTE: It is recommended that starred items be removable from the display by means of a declutter control. Symbols that can be deleted by declutter should have a secondary warning when they are deleted because of faulty data.

a. Fuel range circle. This symbol shall be used to display fuel range on the HSD map. The size of the symbol depends on the changing fuel range and map scale factor (*Figure 60a*).

b. Compass rose. The compass rose shall be used to display aircraft heading and shall be driven by the aircraft navigation equipment. In TRACK UP mode, the compass shall rotate to display aircraft magnetic heading when referenced to the index at the top of the display. In NORTH UP mode, the compass shall remain fixed with north located at the top of the display, and aircraft heading is depicted by the aircraft symbol. Tick marks shall be displayed in ________-degree increments with a longer tick mark every ________ degrees, a numeric in place of a tick mark every ________ degrees, and the letters N (north), E (east), S (south), W (west) to represent the four compass directions (*Figure 60a*).

c. Bearing pointer. The bearing pointer shall be used to indicate the magnetic bearing from the aircraft to the selected ground station (VOR, TACAN, ADF, or INS) (*Figure 60a*).

d. Course deviation indicator (CDI) and scale. The CDI shall be used to display the aircraft position (via the aircraft symbol) relative to a selected course. Once the course arrow has been set, the CDI shall rotate with the compass rose. Full-scale deflection (2 dots) on the CDI scale varies as a function of ground station but typically ranges from three-fourths of a degree per dot to five degrees per dot (*Figure 60a*).

e. Aircraft symbol. The miniature aircraft symbol on the HSD shall be used to represent own-ship position with respect to the navigation situation (*Figure 60a*).

f. Heading marker. The heading reference marker shall be used to provide a reference to the desired heading. It is typically used with the autopilot or flight director computer (*Figure 60a*).

g. To/from symbol. The to/from indicator shall be displayed as a triangular-shaped pointer. When the indicator points to the head of the course arrow, it shall indicate that the course selected, if properly intercepted and flown, directs the aircraft to the selected facility (*Figure 60a*).

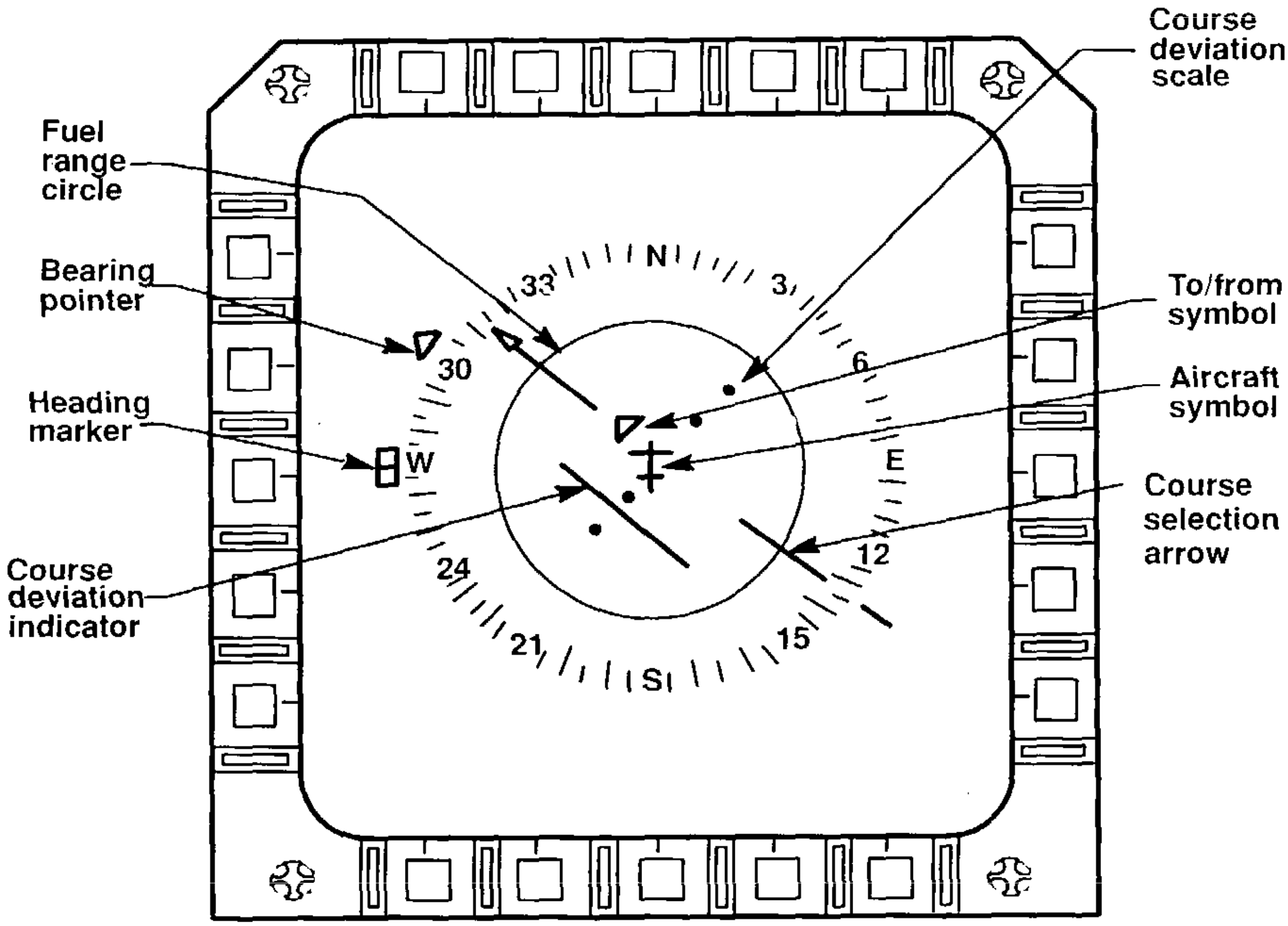


FIGURE 60. a. Typical horizontal situation display.

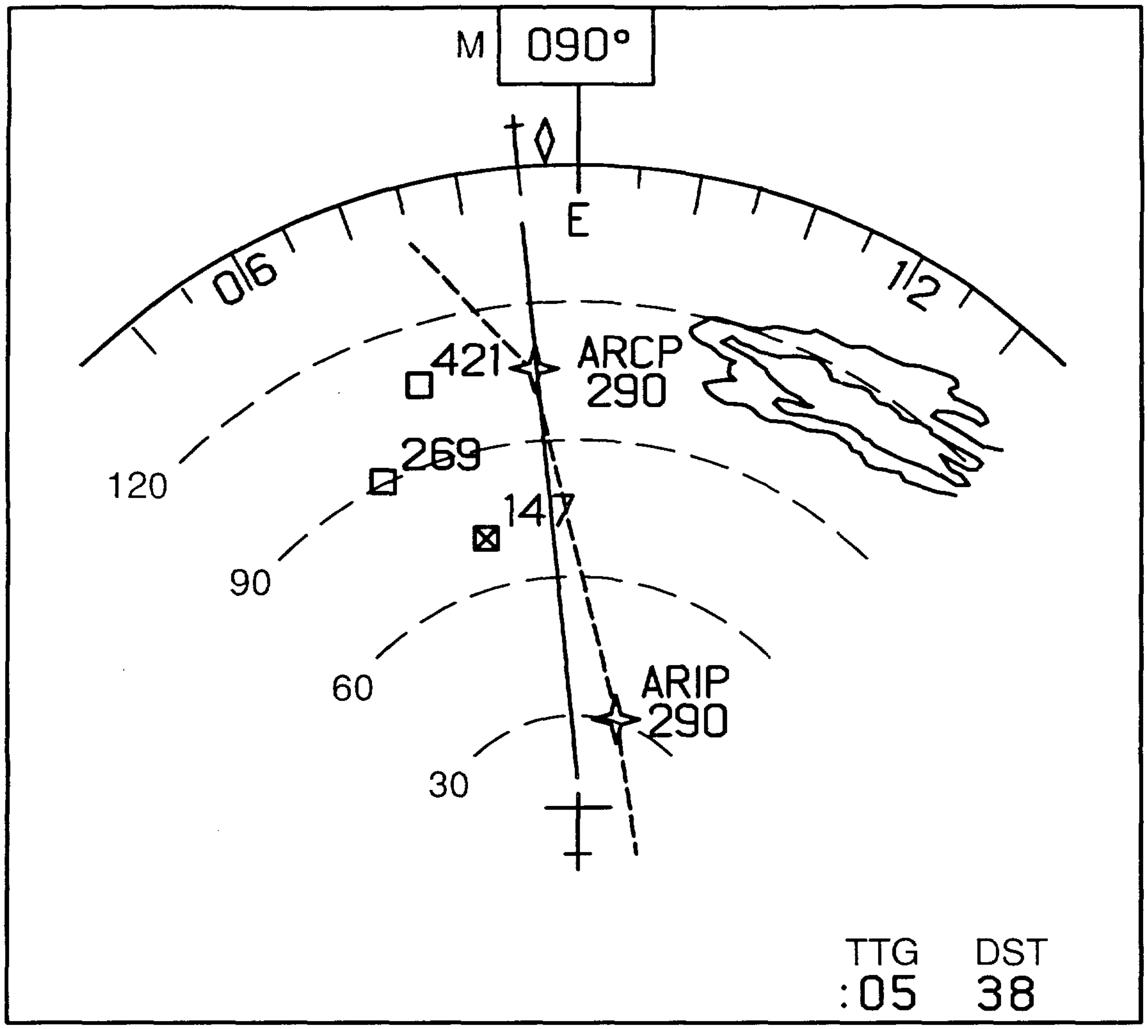


FIGURE 60. b. Arc map display.

4.3.5 Head up display (HUD). The HUD shall present essential flight and combat information. The information presented depends on the requirement of the different modes of operation. *Table II* shows common HUD information requirements and associated symbology for each mode (*Figure 61a* & *61b*).

TABLE II. HUD mode information matrix.

Information Requirements	MODE Take Off	Nav	Tf/ Ta	Weapon Del	Ldg	Figure
Aircraft Pitch Reference Symbol	X*	X*	X*	X*	X*	11
Aiming Reticle				X		37, 38, 57, 58
Airspeed Display	X	X*	X*	X*	X	12
Allowable Steering Error Circle & Steering Dot				X		39
Altitude Display	X	X*	X*	X*	X	15
Angle of Attack Error/Speed Worm					X	10
Azimuth Steering Line				X		41
Bank Angle Scale	X*	X*	X*	X*	X*	21
Beacon Symbol		X	X	X		42
Bombfall Line				X		43
Breakaway Symbol		X	X	X		44
Character Fonts	X	X	X	X	X	59a,b,c
Climb/Dive Angle Scale	X	X*	X*	X*	X	4, 5, 6, 7, 8
Climb/Dive Marker/Flight Path Marker	X*	X	X	X*	X	45
Continuously Computed Impact Line				X*		30
Flight Director Steering					X	2a,b, 3
Gun Cross				X		46
Heading Display	X	X*	X*	X*	X	19
Horizontal & Vertical Deviation		X	X*		X	24, 27
Lead Computing Optical Sight Line				X		47
Longitudinal Acceleration Cue	X	X	X	X	X	9
Missile Aiming Symbol				X		62a,b,c
Pull-up Anticipation Cue				X		48
Radar Range Scale				X		49
Solution Cues				X		59
Steerpoint Index	X	X	X			42
Target Designators		X	X	X		51, 52, 53
Target Identification Set Laser		X		X		55
Target Locator Line				X		54
Terrain Following Cue			X			56
Vertical Velocity Indicator	X*			X*	X*	18

NOTE: It is recommended that asterisked items be removable from the display by means of a declutter control. Symbols that can be deleted by declutter should have a secondary warning when they are deleted because of faulty data.

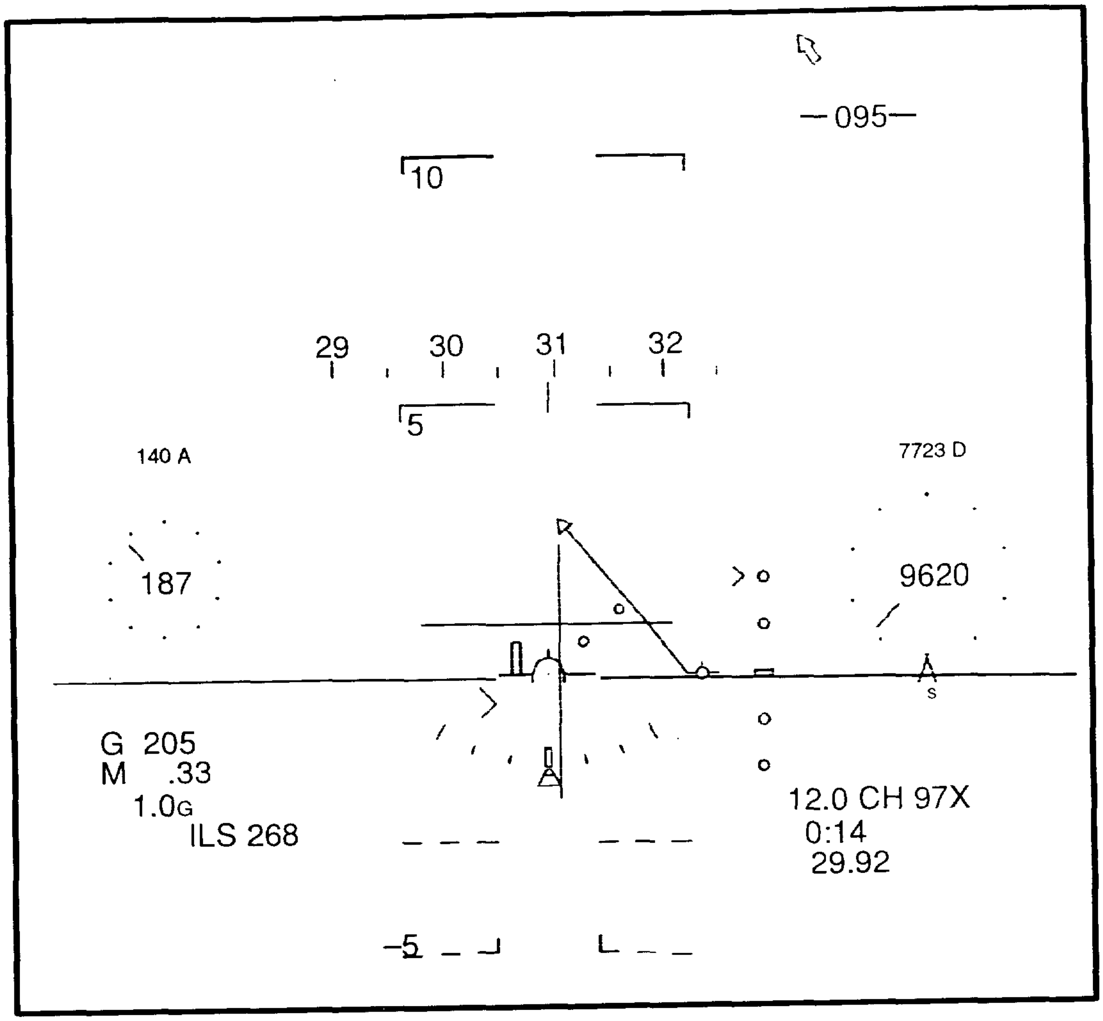


FIGURE 61. a. HUD ILS format.

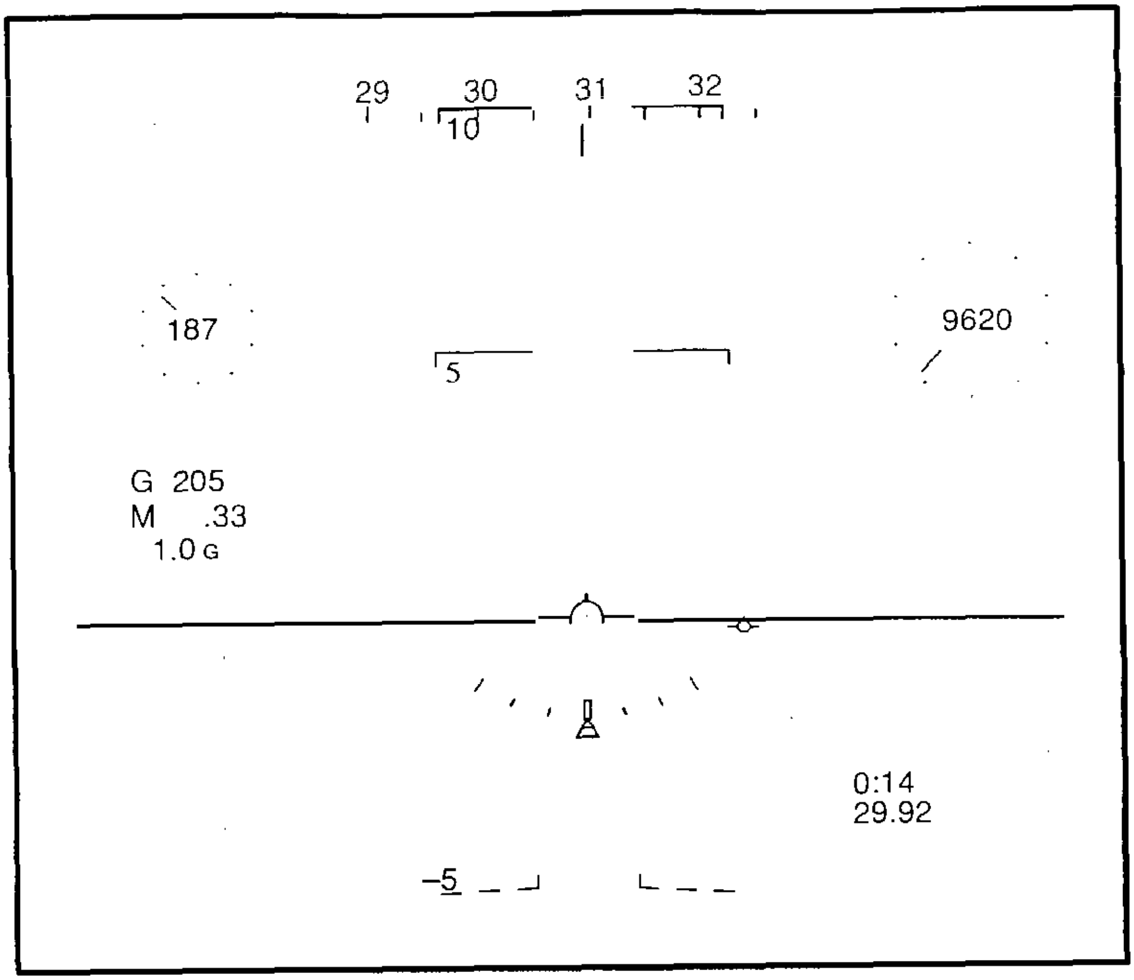


FIGURE 61. b. HUD cruise mode.

4.3.6 Missile aiming symbol. *Figures 62a* through *62c* shall be used as applicable for missile seeker head position on both the HUD and head-down display prior to lock-on, during radar lock-on, and after pilot designation or acceptance of the target the missile seeker is locked on.

a. Missile seeker head line of sight (LOS). This symbol shall represent the LOS of the missile seeker head during search (*Figure 62a*).

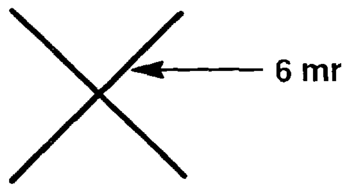


FIGURE 62. a. Missile seeker head LOS.

b. Target lock-on. This symbol shall represent the LOS of the missile seeker head during radar track of the target *(Figure 62b)*.

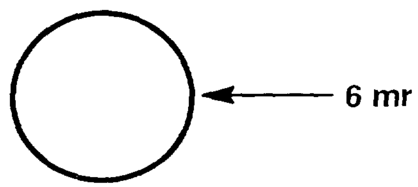


FIGURE 62 b. Target lock-on.

c. Pilot designated target. This symbol shall represent pilot designation or acceptance of the target on which the missile is locked (*Figure 62c*).

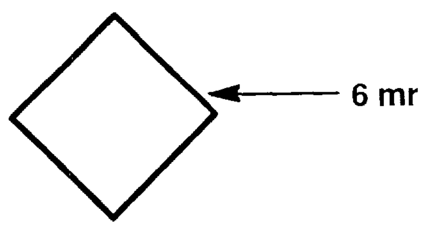


FIGURE 62 c. Pilot designated target.

4.3.7 Runway reference. This symbol shall be used in landing mode to represent the aim point and touch-down point of a runway (*Figure 63*).

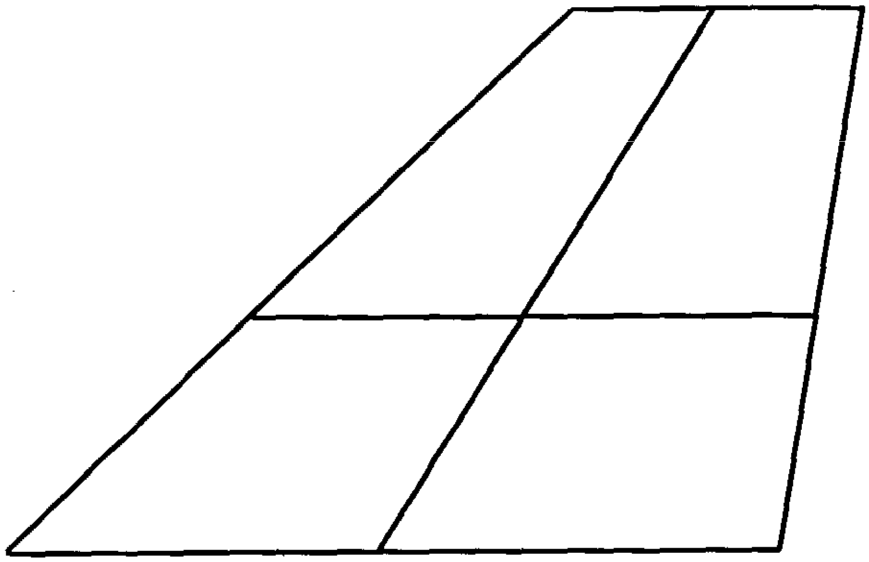


FIGURE 63. Runway reference.

4.3.8 Vertical situation display (VSD). The VSD shall present essential flight and combat information. The information presented depends on the requirements of the different modes of operation. *Table III* is a matrix of suggested information requirements and associated symbology for each mode (*Figures 64a, 64b, & 64c*).

TABLE III. VSD mode information matrix.

Information Requirements	MODE Take Off	Nav	Tf/ Ta	Weapon Del	Ldg	Figure
Acquisition Symbol		X*	X*	X*		34
Aircraft Pitch Reference Symbol	X*	X*	X*	X*	X*	2a,b
Airspeed Display	X*	X*	X*	X*	X*	12
Allowable Steering Error Circle & Steering Dot				X*		39
Altitude Display	X*	X*	X*	X*	X*	15
Angle of Attack Error Display					X*	
Antenna Azimuth & Elevation Markers		X*	X*	X*		40
Attitude Bar	X*	X*	X*	X*	X*	
Azimuth Steering Line				X*		41
Beacon Symbol		X*	X*	X*		42
Bombfall Line				X*		43
Breakaway Symbol		X*	X*	X*		44
Character Fonts	X*	X*	X*	X*	X*	59a,b,c
Course Command, Flight Director		X*	X*		X*	30
Continuously Computed Impact Line				X*		45
Flight Path Angle Display	X*	X*	X*	X*	X*	3
Flight Path Marker	X*	X*	X*	X*	X*	
Gun Cross				X*		46
Heading Display	X*	X*	X*	X*	X*	19
Horizontal & Vertical Bars		X*	X*		X*	
LCOS Line						47
Missile (Aiming Symbol)				X*		62a,b,c
Pull-up Anticipation Cue				X*		48
Radar Range Scale				X*		49
Solution Cues				X*		59
Steerpoint Index	X	X	X			42
Target Designator/Radar Lock-On		X	X	X		51
TISL Reticle		X		X		55
Vertical Velocity Indicator	X			X	X	18

NOTE: It is recommended that asterisked items be removable from the display by means of a declutter control. Symbols that can be deleted by declutter should have a secondary warning when they are deleted because of faulty data.

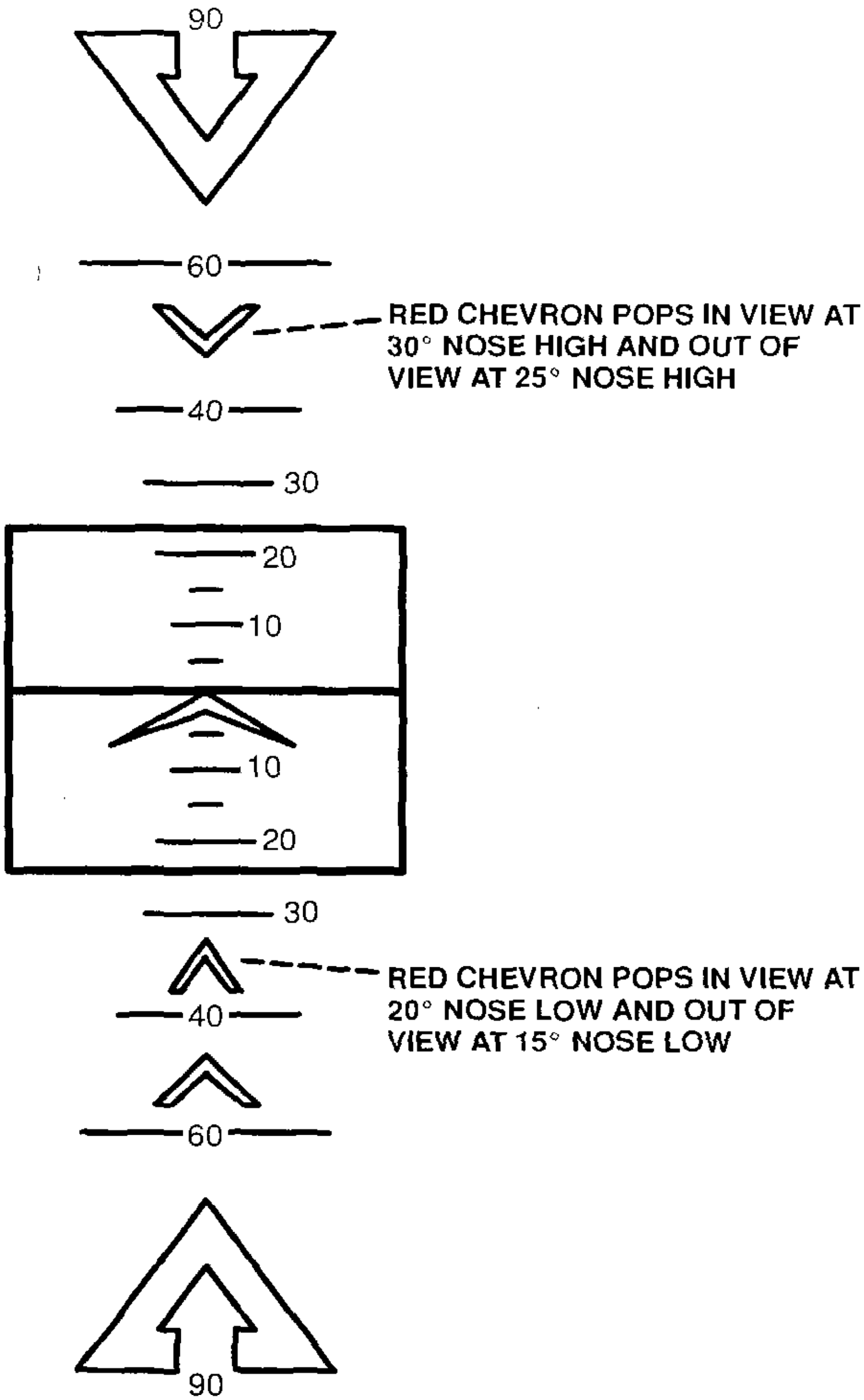


FIGURE 64. a. Electronic attitude director indicator (EADI) display format.

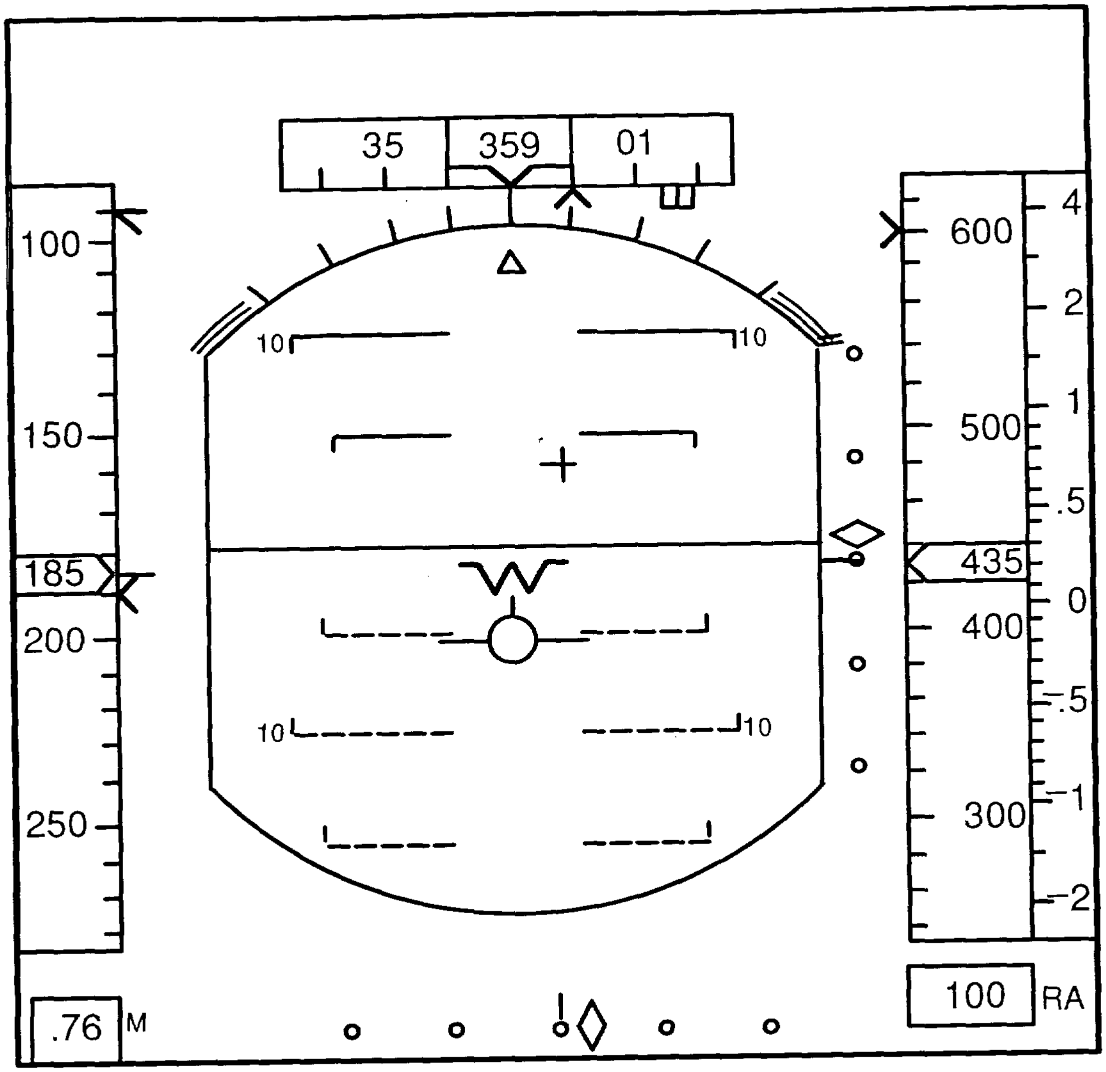


FIGURE 64. b. Transport VSD (landing mode).

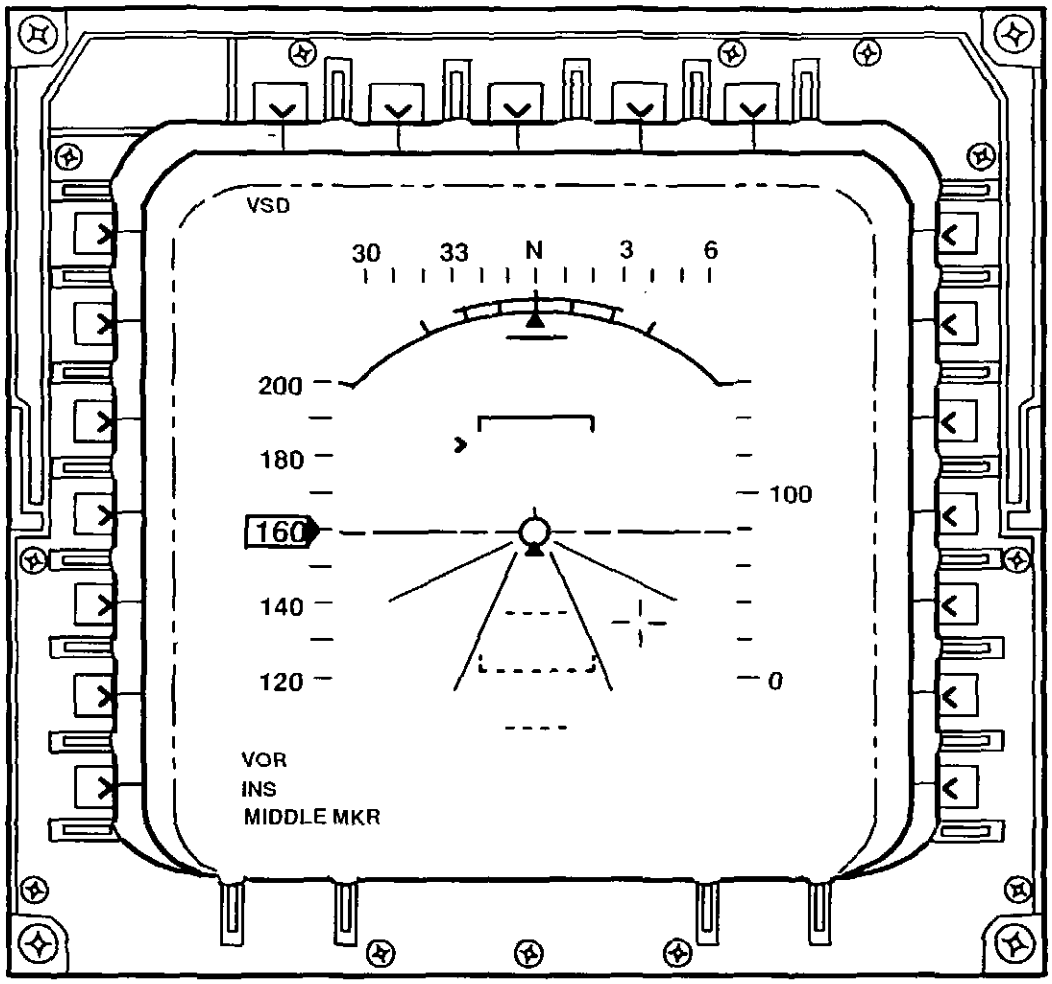


FIGURE 64. c. Typical VSD overlay on FLIR video (not shown).

5. VERIFICATIONS

5.2 Standard symbols verification. All display symbology requirements in section 4 shall be verified by visual inspection of the shape and dimensions of each symbol and alphanumeric character and a functional verification (hot bench test or flight test) of the operational characteristics and mechanization of each symbol using actual system hardware and software.

5.3 Symbols and layouts verification. All display symbology in section 4.3 shall be verified by visual inspection of the shape and dimensions of each symbol and alphanumeric character and a functional verification (hot bench test or flight test) of the operational characteristics of each symbol. New symbols proposed in lieu of those in section 4.3 must provide a justifiable improvement in system capability and must be functionally verified.

6. NOTES. This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.

6.1 Intended use. This document is intended for use in the design of symbols used on electro–optical displays in military aircraft.

6.2 Issue of DODISS. When this standard is used in acquisition, the issue of the DODISS to be applicable to this solicitation must be cited in the solicitation (see *2.1.1*).

6.3 Consideration of data requirements. The following data requirements should be considered when this standard is applied on a contract. The applicable Data Item Descriptions (DIDs) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DIDs are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where *DOD FAR Supplement 27.475-1* exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring

(List any applicable Data Item Descriptions in the tailored document.)

The above DIDs were those cleared as of the date of this standard. The current issue of *DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL)*, must be researched to ensure that only current, cleared DIDs are cited on the DD Form 1423.

6.4 International standardization agreements. Certain provisions of this standard *[may be]* the subject of international standardization agreements (*list here any applicable international standards in the tailored document)*. When amendment, revision, or cancellation of this standard is proposed that will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels, including departmental standardization offices, to change the agreement or make other appropriate accommodations.

6.5 Subject term (key word) list

aiming
altitude
attitude director
bank
bearing
climb bar
cursor
dial
dive bar
flight path marker
fonts
heading
head–up
horizontal situation
HUD
indicator
primary flight reference
pitch reference
readout
reticle
scale
speed
symbol
target
vertical situation

6.6 Responsible engineering office. The office responsible for development and technical maintenance of this standard is ASC/ENFC, Wright-Patterson AFB, OH 45433-7809. DSN 785–8059 (Ext. 4314); commercial (513) 255–8059 (Ext. 4314). Any information obtained relating to Government contracts must be obtained through appropriate contracting officers.

6.7 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

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HANDBOOK FOR
AIRCRAFT DISPLAY SYMBOLOGY

10. SCOPE

10.1 Scope. This appendix provides the information necessary to tailor sections 4 and 5 of the basic standard (*MIL–STD–1787B*) for a specific application. When applicable, alternative symbology is presented within the rationale and guidance sections.

10.2 Format. Each requirement of section 4 of the basic standard is discussed in section 40 of this appendix. The order, paragraph numbering, paragraph titles, and text of section 4 are duplicated in section 40 to facilitate study and tailoring. The discussion of each requirement is divided into three parts:

a. Rationale – The reason why the requirement exists; the purpose that the requirement advances.

b. Guidance – Instructions and formulas for setting the values that are left blank in the basic standard, or for omitting the requirement altogether.

c. Lessons Learned – Summaries of field experience concerning this technical area.

10.3 Responsible engineering office. The responsible engineering office (REO) for this appendix is ASC/ENFC, 2335 Seventh St., Suite 6, Wright–Patterson AFB OH 45433–7809, DSN 785–8059, commercial (513) 255–8059.

20. REFERENCED DOCUMENTS

20.1 Unless otherwise indicated, the documents specified herein are referenced solely to provide supplemental technical data. References listed in section 2 of the standard are applicable but are not repeated in section 20.

20.1.1 Government documents

STANDARDS

Military

MIL–STD–1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL–STD–1776	Aircrew Station and Passenger Accommodations

20.1.2 Other publications

AFFDL–TR–70–174. *Analysis of Human Factors Data for Electronic Flight Display Systems.*

ASD–TR–81–5014. *A Simulation Study of the Use of JTIDS in Tactical Missions.*

JANAIR Report No. 680505. *Electronically and Optically Generated Aircraft Displays.* "A Study of Standardization Requirements," May 1968.

WRDC–TR–90–7009. *Development of an Enhanced MIL–STD–1787 Dot Matrix Font.* (DTIC #ADB151907)

30. DEFINITIONS, ABBREVIATIONS AND ACRONYMS

The definitions, abbreviations, and acronyms in section 3 of the standard apply to this appendix. Those listed below are used only within the supplemental appendix information.

ADI – attitude director indicator
AOA – angle of attack
ARP – aircraft reference point
CSEF – Crew Station Evaluation Facility
INS – inertial navigation system
JTIDS – Joint Tactical Information Distribution System
LANTIRN – Low Altitude Navigation Targeting Infrared for Night
LLLTV – low light level television
MFD – multifunction display
NATO – North Atlantic Treaty Organization

40. REQUIREMENTS AND VERIFICATIONS

4.1 Information content of the display. Displays shall present information needed for all instrument flight maneuvers to include takeoff, navigation, and landing. Symbols and symbol formats shall be integrated with emphasis on enhancing the pilot's spatial orientation and situational awareness while minimizing display clutter, particularly when visibility is poor.

REQUIREMENT RATIONALE (4.1)

Displays which present essential information in the form of a moving diagram or abstract animation have proven extremely effective in aiding aircrew performance.

REQUIREMENT GUIDANCE (4.1)

Use *Table A–I* as guidance in designing instrument flight display and determining what information should be considered for inclusion in a display. Omit mission segments and items of information which do not apply to the system in question. If it seems necessary to add other information to the display, symbology should be in accordance with this standard.

TABLE A–I. Data required during specific instrument flight maneuvers.

Required Data	*Maneuver*										
	Instrument T/O	Climb	Cruise	Fix-to-Fix	Hold	Penetration	Arc	Non-Precision	Precision	Flt Dir App	Cat II/III
Precise Pitch Angle	X										
Climb/Dive Angle [1,2]	X	X	X	X	X	X	X	X	X	X	X
Precise Bank Angle	X	X	X	X	X	X	X	X	X	X	X
Barometric Altitude	X	X	X	X	X	X	X	X	X	X	X
Airspeed	X	X	X	X	X	X	X	X	X	X	X
Heading	X	X	X	X	X	X	X	X	X	X	X
Horizontal Flt Path[3]	X						X	X	X	X	X
Bearing	S	S	S	S	S	S	S	S	S	S	S
Distance	S	S	S	S	S	S	S	S	X	X	X
Lateral Deviation		X	X		X	X		X	X	X	X
Vertical Deviation						M/G			X[5]	X	X
Flight Director										X	X
Timing					S	S	S	S	S	S	X
Absolute Altitude											X
Angle-of-Attack[4]	X	X	X	X	X	X	X	X	X	X	X
Yaw[4]	X	X	X	X	X	X	X	X	X	X	X
Longitudinal Accel	R	R	R	R	R	R	R	R	R	R	R
Speed/AOA Dev	R	R	R	R	R	R	R	X	X	X	X

Legend:

X = Always required for this maneuver on single medium PFR
M/G = Required only for MLS or GPS curved path procedure
S = Required only if this data is not in view elsewhere in the cockpit (single source)
R = Strongly recommended for this maneuver

Notes:

1. Replaced by pitch and vertical velocity when the climb/dive marker (CDM) is invalid or unavailable.
2. Vertical velocity added to the display when the aircraft is in a high AOA, CDM limited condition.
3. Required only on displays that are designed to conform to an outside visual scene or display (e.g., HUD, FLIR or Radar imagery overlays).
4. Required only for aircraft which require this data due to aircraft limitations, asymmetric drag/thrust.
5. Not required for PAR approaches.

4.1.1 Primary flight reference (PFR) data. All pilot crew stations from which a pilot is to control an aircraft shall have at least one complete set of PFR data meeting the following requirements: A PFR shall provide the pilot flying the aircraft with the information required to accomplish an instrument maneuver during a mission segment and shall enable the pilot to maintain attitude awareness and to recover from an unusual attitude. A single-medium primary flight reference shall present the required information on a single medium such as a multifunction display, head-up display, or helmet-mounted display. The PFR shall be a prominent, centrally located display.

a. Location. A complete set of primary flight data shall be presented either head up or head down at all times. If the primary flight data is located head up, a head-down presentation shall be immediately available from only one hands-on switch action by the pilot. A head-up PFR shall subscribe to location criteria for head-up displays. The head-down PFR shall be centrally located within the pilot's normal scan pattern on the instrument panel. Vertical stacking on top of the primary navigation display is preferred; however, a side-by-side arrangement with the PFR on the left is acceptable. If both a head-up and head-down PFR are presented, the head-down PFR shall be located on the instrument panel as previously described and within 25 degrees of the horizontal axis of the center of the HUD field of view (FOV) (*Figure 1a*).

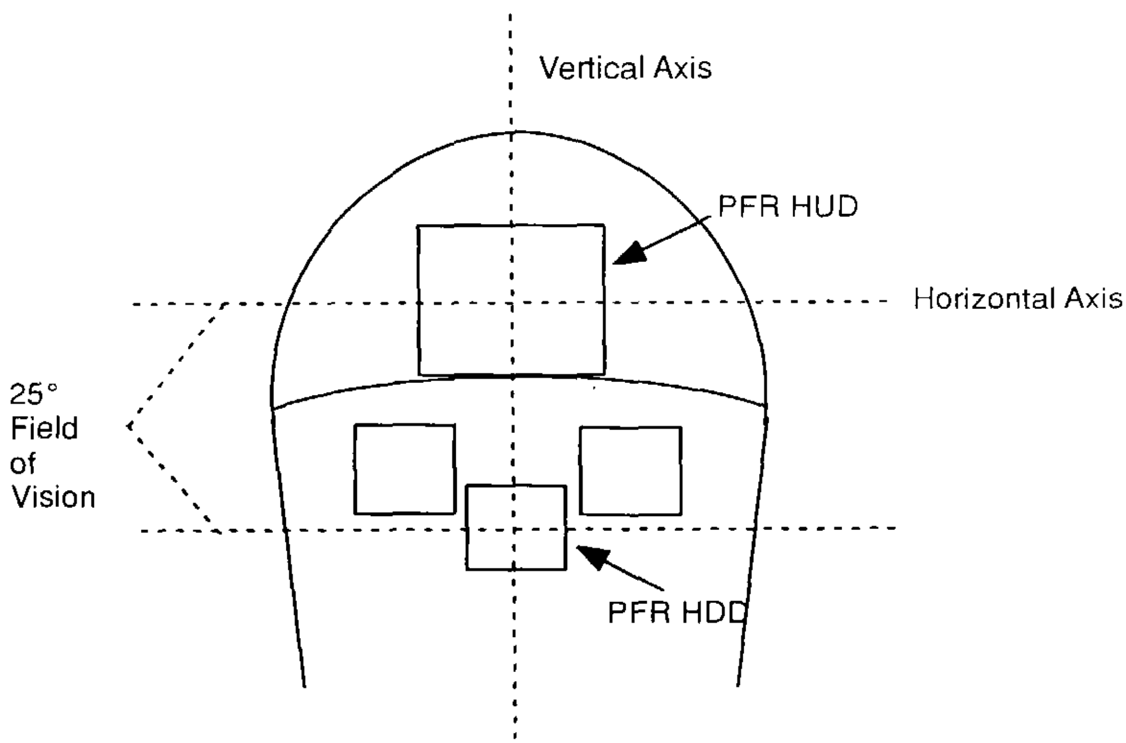


FIGURE 1. a. Preferred location of head-up and head-down primary flight reference displays.

b. Critical flight data. A PFR shall always provide the following critical flight data:

(1) Climb/dive angle (pitch and vertical velocity if a single symbol representing the climb/dive angle is invalid or unavailable) shall be centrally located within the PFR and shall provide the crew member with a minimum coverage angle of ________.

(2) Bank
(3) Altitude
(4) Airspeed

c. Data for instrument maneuvers. When the following data is required for an instrument maneuver it shall be provided in the PFR:

(1) Heading
(2) Bearing
(3) Distance
(4) Lateral and vertical deviation from a selected course and glide path
(5) Flight director and an indication of absolute altitude (category II and III approaches)
(6) Angle of attack
(a) and sideslip
(b) when required by aircraft design

d. Supplemental flight data. The following information is not required in the PFR but shall be in the viewing area of the pilot flying the aircraft:

(1) Power indication
(2) Altimeter setting (when monitoring barometric altitude)
(3) Selected course
(4) Timing

e. Non-PFR data. Additional information included on the display(s) containing the PFR shall not interfere with maintaining attitude awareness or recovering from an unusual attitude.

f. Failure indication. Failure indication of any required data shall be provided in the PFR.

g. Declutter. Symbols that can be deleted by decluttering should have a secondary warning when they are deleted because of faulty data.

REQUIREMENT RATIONALE (4.1.1)

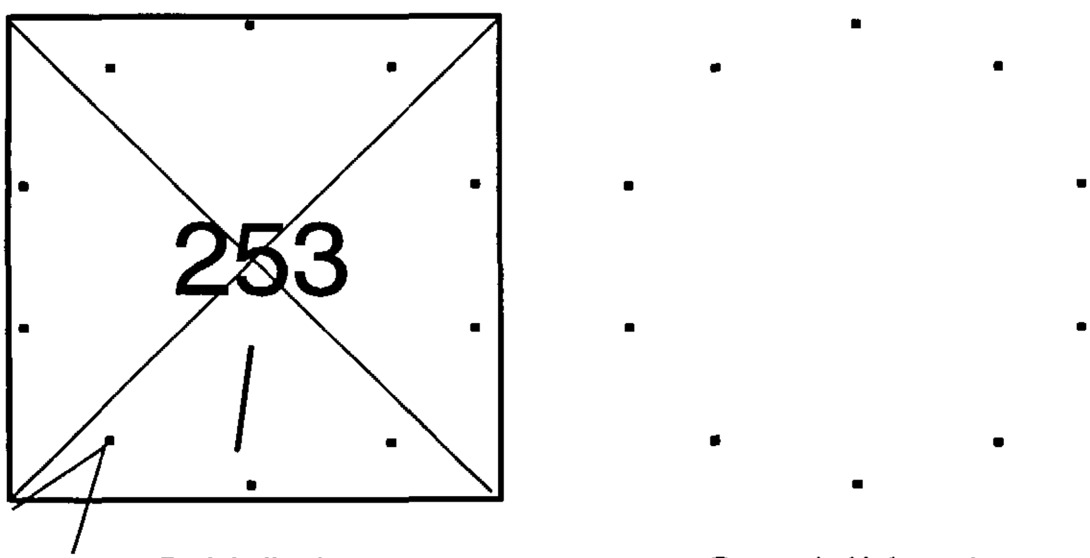
The standardized cockpit configurations built around the integrated flight instrument system (attitude director indicator/horizontal situation indicator—ADI/HSI) have given way to head-up displays (HUDs) and multifunction displays (MFDs). These displays can be programmed to show information in almost any form. Mission specialized displays have helped provide a substantial increase in weapon system effectiveness. The same flexibility provided by the programmability of the HUDs and MFDs creates a need for a suitable standard for such devices to ensure that essential flight information is provided to the crew member in a timely and effective manner.

REQUIREMENT GUIDANCE

The flight information requirements defined in 4.1.1 shall be included in all aircraft pilot stations. In general, the guidance provided in *Table A–I* should serve as a baseline for development of flight instrument displays. The table outlines specific information needs to perform various instrument maneuvers.

The most important attribute of any primary flight reference display is its effectiveness in conveying to the pilot the current status of the aircraft to ensure safety of flight. It is not surprising that the attitude indicator has proven to be the central instrument of an effective cross-check since it can immediately alert the pilot to an unsafe flight condition. Current electromechanical ADIs are capable of providing up to 90 degrees of pitch attitude coverage. Current HUDs are capable of providing up to 20–25 degrees of attitude coverage. This loss of coverage when going from the ADI to HUD display of attitude information can potentially reduce the pilot's ability to acquire attitude information readily. The HUD field of coverage is limited primarily by technology and the ability to provide wide field-of-view HUDs. However, the head-down electronic attitude director indicator (EADI) does not have such limitations and should not be limited to the same coverage angles as the HUD. Therefore, for head-down PFR presentation, the climb/dive angle display shall present a minimum of +/– 30 degrees attitude coverage. Head-up presentation shall provide the maximum FOV attainable with the HUD. An absolute minimum of +/–10 degrees shall be provided whenever the PFR is being displayed.

Adequate fault indication is essential for the safe use of any primary flight reference. Presentation of false or inaccurate primary flight information is unacceptable and places the pilot and crew at significant risk. For this reason, effective fault indication of failed or erroneous information is mandatory. An effective means of fault identification and presentation for primary flight information is to bring the failure to the attention of the crew by highlighting the offending symbology. This should be accomplished by boxing and crossing out the symbol (*Figure 1b*). Once the fault has been acknowledged by the crew, the fault indication along with the erroneous information should be removed from the display.



Fault Indication

Removal of information after crew acknowledgement

FIGURE 1. b. Positive fault indication.

4.2 Standard symbols. Symbols for the functions described under 4.2 shall have the geometry shown in the figures accompanying each paragraph in the standard.

REQUIREMENT RATIONALE (4.2)

The symbols defined in section 4.2 are based on standard symbols which have evolved as a result of flight tests, operational use, and human factors criteria related to symbol interpretability on electronic displays.

REQUIREMENT GUIDANCE (4.2)

The symbols defined in section 4.2 should be used whenever possible for displays in Air Force fixed wing aircraft. It should be noted that the majority of the symbols provided in section 4.2.1 were developed primarily for use in head-up displays, although in some cases, they may be applied to other display media. Since most Air Force aircraft use only a part of the recommended standards, compromises are necessary to maintain commonality within an existing aircraft program. This standard should still be used to develop symbols and formats for new systems being integrated into existing aircraft programs.

REQUIREMENT LESSONS LEARNED (4.2)

The display generator chosen for a display system may ultimately dictate the type of characters that can be displayed before symbology requirements have been properly identified. If symbology processing requirements cannot be met with the display generator selected for the system, a compromise to the symbology is normally made in lieu of a costly hardware modification. Such compromises are often made at the expense of the pilot/vehicle interface. It is important, therefore, that functional display requirements are sufficiently detailed to ensure that the capabilities of the display hardware meet the functional requirements of the pilot interface.

5.2 Standard symbols verification. All display symbology requirements in section 4 shall be verified by visual inspection of the shape and dimensions of each symbol and alphanumeric character and a functional verification (hot bench test or flight test) of the operational characteristics and mechanization of each symbol using actual system hardware and software.

VERIFICATION RATIONALE (5.2)

Visual inspection is adequate to verify shape and dimensions of each symbol and alphanumeric character. Hot bench or flight tests are adequate to verify the operational characteristics of each symbol.

VERIFICATION GUIDANCE (5.2)

Verification of the symbols chosen should be performed during human factors test and evaluation of the full-scale development effort. Progress should be monitored, however, from the initial design to final development to ensure continued compliance with the requirements. Symbol geometry, font, format, dimensions, and mechanizations are normally defined in the development specifications for each of the displays being used. Display resolution, brightness, uniformity, contrast, flicker, noise, minimum line movement, etc., are display characteristics which are specified in *AFGS–87213*. *MIL–STD–1776* deals with flight instrument displays, control panel layout (legends), and color lights. *MIL–STD–1472* contains a section on human factors display requirements.

VERIFICATION LESSONS LEARNED (5.2)

4.2.1 **Aircraft reference symbology**

4.2.1.1 **Climb/dive marker.** The climb/dive marker (CDM) (*Figure 2a*) shall display the current climb/dive angle when read against a climb/dive ladder. The CDM shall be free to move along the vertical axis within the instantaneous field of view (IFOV) to present the climb/dive angle accurately. If the aircraft's climb/dive angle requires the positioning of the CDM outside the limits of the display's IFOV, the CDM shall be limited and replaced by the dashed climb/dive marker (*Figure 2b*). The CDM or dashed CDM shall be visible within the display's IFOV at all times.

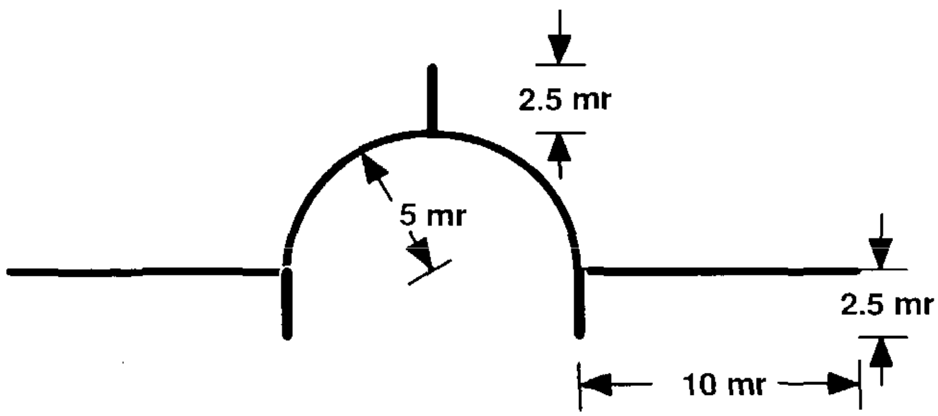


FIGURE 2. a. Climb/dive marker (CDM).

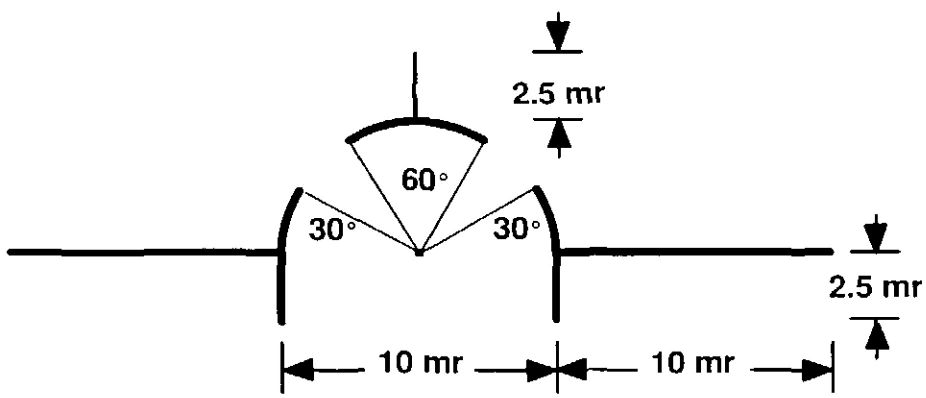


FIGURE 2. b. Dashed climb/dive marker.

REQUIREMENT RATIONALE (4.2.1.1)

Pilots have become accustomed to using the HUD as a source of primary flight information. One of the fundamental benefits of the HUD, and therefore one of the reasons it has achieved such wide use, is the presentation of the flight path marker (FPM) as the primary control reference. Using traditional pitch referenced displays requires the pilots to integrate their pitch attitude, vertical velocity, and angle-of-attack to determine aircraft flight path. The incorporation of the FPM has eliminated the need for these mental interpretations by indicating where the aircraft is going rather than where it is pointing (i.e., pitch attitude).

The flight-path-referenced HUD has one major deficiency that has, in part, prohibited the adoption of it as a primary flight reference display by the Air Force. Being a performance-based reference, the FPM indicates the performance characteristics of the aircraft, namely where the aircraft is going. Unlike a pitch reference, which indicates where the nose of the aircraft is pointing and thus can be displayed as a fixed reference marker, the FPM's position changes based on the dynamic characteristics of the aircraft, the maneuver it is performing, and the atmospheric conditions in which the aircraft is flying (i.e., winds).

This displacement of the FPM can cause two undesirable effects. First, the displacement of the FPM also displaces all the symbols that are positioned relative to the FPM (i.e., instrument landing system/tactical air navigation (ILS/TACAN) symbology, climb/dive ladder). The motion and displacement of the symbols make the HUD symbology more difficult to read. In extreme cases, crosswind effects may cause displacement of the FPM to overwrite or interfere with the interpretation of other primary flight information (i.e., altitude and airspeed scales). Second, during dynamic maneuvering, the displacement of the FPM can make it difficult to use the symbol as a source of attitude information. In fact, under conditions of high bank angle and high g-loading, the FPM, along with the climb/dive ladder, can disappear from the display leaving the pilot with no attitude reference whatsoever.

To compensate for these shortcomings a quickened climb/dive marker (CDM) has been adopted. The CDM is similar in fashion to the drift cutout mode currently implemented in the F–16 and F–15. This implementation maintains the lateral position of the control reference (i.e., CDM) on the HUD centerline.

Inasmuch as the caging of the CDM to the centerline of the HUD eliminates the adverse effects of lateral displacement of the control reference, quickening has been incorporated to compensate for CDM displacement in the vertical axis. Quickening is a means of compensating for the effects of aircraft inertia on the position of the CDM and FPM within the HUD FOV by calculating an estimate of the instantaneous CDM displacement caused by these lags.

The adoption of a quickened CDM has several advantages as a primary control reference as compared to the FPM; they are as follows:

a. The vertical displacement of the control reference during aircraft maneuvering is greatly reduced.

b. The lateral displacement of the control reference due to sideslip and winds is eliminated.

c. Since stability of the control reference is greatly enhanced by the incorporation of the quickened CDM, the stability of all symbology referenced to the CDM is also improved.

d. Quickening of the CDM more accurately displays the resultant climb/dive angle of instantaneous control inputs because the quickening filter is tuned to compensate for the transient lags in flight path caused by aircraft inertia.

REQUIREMENT GUIDANCE (4.2.1.1)

Because there are significant differences in how the CDM and FPM are used, it is necessary to apply quickening differently to each to accommodate the unique functionality of the two symbols.

Because the FPM is an earth-referenced symbol, it is important that the incorporation of quickening does not cause the symbol to lose correlation with the objects or features of the outside visual scene. The CDM, on the other hand, is an aircraft-referenced symbol serving as the primary control reference to the pilot. In this case, stability during all phases of flight is the paramount consideration. For these reasons, the FPM should be quickened using pitch attitude filter, while the quickener used for the CDM should use pitch Euler rate or body axis pitch rate filter during up-and-away flight. However, the aircraft dynamics during the approach and landing dictate that the CDM be filtered using a pitch attitude quickener during this phase of flight.

The reason for using the alternative quickener for the CDM can be easily demonstrated. The primary objective of the quickener is to maintain stability of the CDM during dynamic maneuvering. Consider the situation in which the aircraft is in a hard-g, high-banked turn. Under these conditions, the pitch attitude of the aircraft does not change, resulting in little or no quickening compensation if a pitch attitude filter were solely implemented. Unfortunately, the instantaneous angle of attack (AOA) resulting from the high-g turn causes considerable CDM displacement. A filter that compensates for CDM displacement based on body axis pitch rate would be able to maintain stability of the control reference during all such phases of aircraft up-and-away maneuvering.

These advantages were demonstrated in evaluations conducted by the Naval Air Test Center which concluded that during approach and landing, a washed-out pitch attitude filter resulted in superior performance relative to an unquickened control reference. Meanwhile, a Euler pitch rate filter was more appropriate for the highly dynamic maneuvers which are more likely to occur during up-and-away flight.

A HUD primary flight reference display, particularly the type used in fighter/attack aircraft, should implement both forms of quickening.

The pitch washout filter (earth axis), Q1, should be used to quicken the FPM and climb/dive ladder at low pitch angles and to quicken the CDM in landing mode. The pitch rate lead filter (aircraft axis), Q2, should be used to quicken the CDM in normal flight and to quicken the FPM, climb/dive ladder, and CDM at high pitch angles.

The following set of equations were used during the Air Force HUD symbology validation program, which cleared the use of the HUD as a primary flight reference. These equations define the quickening terms Q1 and Q2 ...

θ = Aircraft pitch angle
ϕ = Aircraft roll angle
θ_a = Aircraft pitching rate, aircraft axis
G_1, G_2 = Quickener gains

$$Q_1 = G_1 \cos\phi \frac{\tau s \theta_a}{\tau s + 1} \quad \text{Pitch washout}$$

$$Q_2 = G_2 \frac{\tau s \theta}{\tau s + 1} \quad \text{Pitch rate lead}$$

... where s is the *La place* complex frequency variable, and τ is the time constant that controls the rate of washout.

According to research conducted by the Royal Aerospace Establishment, in fighter type aircraft, the time constant τ may be assumed to vary as

$$\tau = A + \frac{B}{v_t \sigma}$$

Where: A and B are constants
v_t is the aircraft's true airspeed and
is the relative density ratio

Tuning of the Time Constant

It remains the determine the optimum values for both A and B which provide the best match between the quickener and the dynamic characteristics of the aircraft over the full flight envelope and range of configurations and masses of the vehicle.

The method proposed here was originally adopted and implemented by the engineers at the Royal Aerospace Establishment, Bedford England (Hall and Penwill, 1989) and is as follows:

a. Determine τ at two flight conditions widely separated in $v_t \sigma$ (See section on tuning of time constant)

For the Crew Station Evaluation Facility's (CSEF, ASC/ENFC, Wright-Patterson AFB, OH) F–16 simulator, the flight conditions chosen were

(1) A representative normal attack speed and configuration (i.e., 400 knots at 1000 to 2000 ft)

(2) Slow speed (i.e., 250 knots at 1000 to 2000 ft)

b. Determine A and B from the two values of τ so defined

c. Ascertain that the operation of the quickener is defined at alternative speeds, heights, aircraft configurations, and aircraft masses to ensure that the value of τ is adequately predicted over the full flight envelope of the vehicle.

The process of tuning the quickener time constant requires the following facility capabilities:

(1) Time constant. The time constant should be programmed to vary as

$$\tau = A + B/(v_t\, \sigma) + \Delta\tau$$

where $\Delta\tau$ is used during the tuning process to vary τ. This method of adjusting τ compensates for small errors in speed and height during the aircraft maneuvers used to tune the quickener.

The operator must be able to change the values of A, B, and $\Delta\tau$ while the simulator is flying.

(2) Quickener gain. The operator must be able to change the value of the quickener gain while the simulator is flying. In particular, the operator must be able to change the quickener gain between 0.7 and 1.0.

(3) Fixed cross. The operator must be able to select and display a fixed reference mark in the HUD and to position this reference anywhere on the vertical centerline of the display.

d. Set quickener gain to 1.0, constants A and Deltau to zero, and constant B to 300.0

(This value for B is designed to increase the rate at which the tuning process converges).

e. Select the fixed reference in the display.

f. Stabilize the aircraft at 400 knots and 1500 ft; move the fixed cross so that it overlays the CDM.

g. Increase the flight path angle by +5 degrees using the quickened CDM and pitch ladder. Note the movement of the aircraft symbol relative to the fixed cross.

h. If the CDM lags the fixed cross, the time constant is too short and should be increased. Similarly, if the CDM leads the fixed cross, $\Delta\tau$ should be decreased.

i. Repeat step 5 using flight path changes of +/–5 and +/–10 degrees and a range of pitch rates. After each test, allow at least 5 seconds for the quickener to stabilize before making a further input. It is unlikely that all relative movement can be eliminated as a first order quickener is being used to match a higher order system having a predominant first order mode. The operator should, therefore, aim to obtain the best match for a range of inputs of varying magnitude and rate. If two values of $\Delta\tau$ give equally good matches then these alternatives should be evaluated with the quickener gain set to 0.7 and the value giving the best handling qualities should be selected. The aim, during the final iteration, should be for $\Delta\tau$ to be within +/– 0.01.

j. Record the values of true airspeed (v_{t1}), relative density ratio (σ_1) and $\Delta\tau_1$ appropriate to this test condition (400 knots/1500 ft). Provided v_{t1} and σ_1 are recorded at the same point in time, then small variations in speed and height during the test maneuvers are taken into account.

k. Reset $\Delta\tau$ to zero and repeat steps 2 through 7 for 250 knots and 1500 ft.

l. Record values of v_{t2}, σ_2, and $\Delta\tau_2$ for this second flight condition.

m. Compute new values for A and B using the following expressions:

$$\tau_1 = A_{old} + [B_{old}/(v_{t1}\,\sigma_1)] + 1 \quad A_{new} = [\tau_1\, v_{t1}\,\sigma_1 - \tau_2\, v_{t2}\,\sigma_2]/[v_{t1}\,\sigma_1 - v_{t2}\,\sigma_2]$$
$$\tau_2 = A_{old} + [B_{old}/(v_{t2}\,\sigma_2)] + \Delta\tau_2 \quad B_{new} = [\tau_1 - \tau_2]\,[v_{t1}\,\sigma_1\, v_{t2}\,\sigma_2/(v_{t1}\,\sigma_1 - v_{t2}\,\sigma_2)]$$

n. Reset $\Delta\tau$ to zero and repeat steps 3 through 10 with these new values of A and B until $\Delta\tau_1$ is less than +/–0.02 and $\Delta\tau_2$ is less than +/–0.01 (i.e., τ at the two flight test conditions is defined to an accuracy of around +/–1 percent).

o. Reset the quickener gain to 0.7 and evaluate the handling qualities of the vehicle at both the above test conditions.

p. Reset the quickener gain to 1.0. Check the operation of the quickener, by evaluating the relative movement between the CDM and the fixed reference at a sufficient number of alternative speeds, heights, aircraft configurations and aircraft masses to ensure that τ is adequately predicted over the full operational flight envelope and range of configurations and masses of the aircraft. Where there is doubt as to the match, the handling qualities of the vehicle should be evaluated at that condition with the quickener gain set to 0.7.

As a minimum, the tuning of the quickener should be checked at

– Three speeds at three heights to cover the full range of these operating conditions

– Three aircraft masses at one or two critical operating conditions

There is no further opportunity to tune the quickener. If a satisfactory match is not obtained at any operating condition, then the simple form adopted for the variation of τ with flight condition and aircraft configuration must be reappraised.

q. Reset the quickener gain to 0.7.

Note: The time constant τ used in the expression for Q1 should be forced to a small value (e.g., 0.3 sec) above 60 degrees absolute theta in order to speed the recovery of the filter after theta-dot has changed sign through the zenith and nadir.

Blending of Q1 and Q2

In order to avoid inconsistencies in the climb/dive ladder and the flight path marker as the climb/dive angle increases through the zenith and nadir, the quickener used to compensate the ladder and FPM (i.e., Q1) must be blended into a pitch rate quickener (i.e., Q2) at the higher climb/dive angles. The following terms, B1 and B2, are used to blend Q1 and Q2 between low and high pitch angles.

$$B_2 = \begin{cases} 0 & |\theta| \leq 30^\circ \\ \dfrac{|\theta| - 30^\circ}{55^\circ - 30^\circ} & 30^\circ < |\theta| < 55^\circ \\ 1 & |\theta| \geq 55^\circ \end{cases}$$

$$B_1 = \begin{cases} 1 & |\theta| \leq 30^\circ \\ 1 - B_2 & 30^\circ < |\theta| < 55^\circ \\ 0 & |\theta| \geq 55^\circ \end{cases}$$

During normal flight:

$$FPMQ = CDLQ = Q_1 \times B_1 + Q_2 \times B_2$$
$$CDMQ = Q_2$$

During ILS mode or landing gear down:

$$FPMQ = CDMQ - CDLQ = Q_1 \times B_1 + Q_2 \times B_2$$

Caging of the CDM

Caging is a means by which the lateral displacement of the FPM is restricted to reduce the adverse effects of large beta angle caused by excessive crosswinds or sideslip. The concept of the caged FPM (i.e., climb/dive marker) as the primary control reference is not a new idea, as many current aircraft including F–16 and F–15 incorporate a similar feature called drift cutout. The benefit of the climb/dive marker (CDM) and drift cutout is that it stabilizes the primary flight reference symbology on the lateral centerline axis of the HUD by removing the effect of beta (i.e., drift due to winds or sideslip).

The following set of equations position the FPM, CDM, and climb/dive ladder (CDL). When positioning the FPM and CDM, a positive azimuth angle is to the right of the aircraft reference point (ARP) and a positive elevation angle is above the ARP.

The FPM's position relative to the ARP is dependent on the aircraft's true velocity vector. The following equations locate the FPM as an azimuth and elevation displacement, in degrees, from the ARP.

uA = Velocity X Body Axis (positive along aircraft axis)

vA = Velocity Y Body Axis (positive out right wing)

wA = Velocity Z Body Axis (positive down)

The following intermediate equation is used in positioning the CDM and climb/dive ladder:

ϕ = Aircraft Roll Angle (positive right wing down)

$$VV_{el} = FPM_{el} * \cos\phi - FPM_{el} * \sin\phi$$

The CDM's position relative to the ARP is defined in the following equations:

α = Aircraft Angle of Attack

$$CDMAZ = 0.0$$
$$CDMEL = VVEL \times \cos\phi - \alpha \times \sin^2\phi + CDMQ$$

The climb/dive ladder is positioned relative to the CDM using the following equation:

$$CDLEL = VVEL + + CDLQ$$

Unfortunately, if the CDM is to remain fixed on the vertical centerline of the HUD thus allowing no lateral movement of the symbol, conformality between the HUD horizon line and the real world horizon line cannot be maintained during high-drift/high-bank-angle maneuvers. One compromise is to allow slight lateral movement of the CDM to maintain full-time horizon correlation. With such an implementation, the amount of the lateral displacement becomes a function of the magnitude of the beta angle, bank angle and angle-of-attack such that maximum horizontal deflection of the CDM is achieved when the beta angle, bank angle and angle-of-attack are all high.

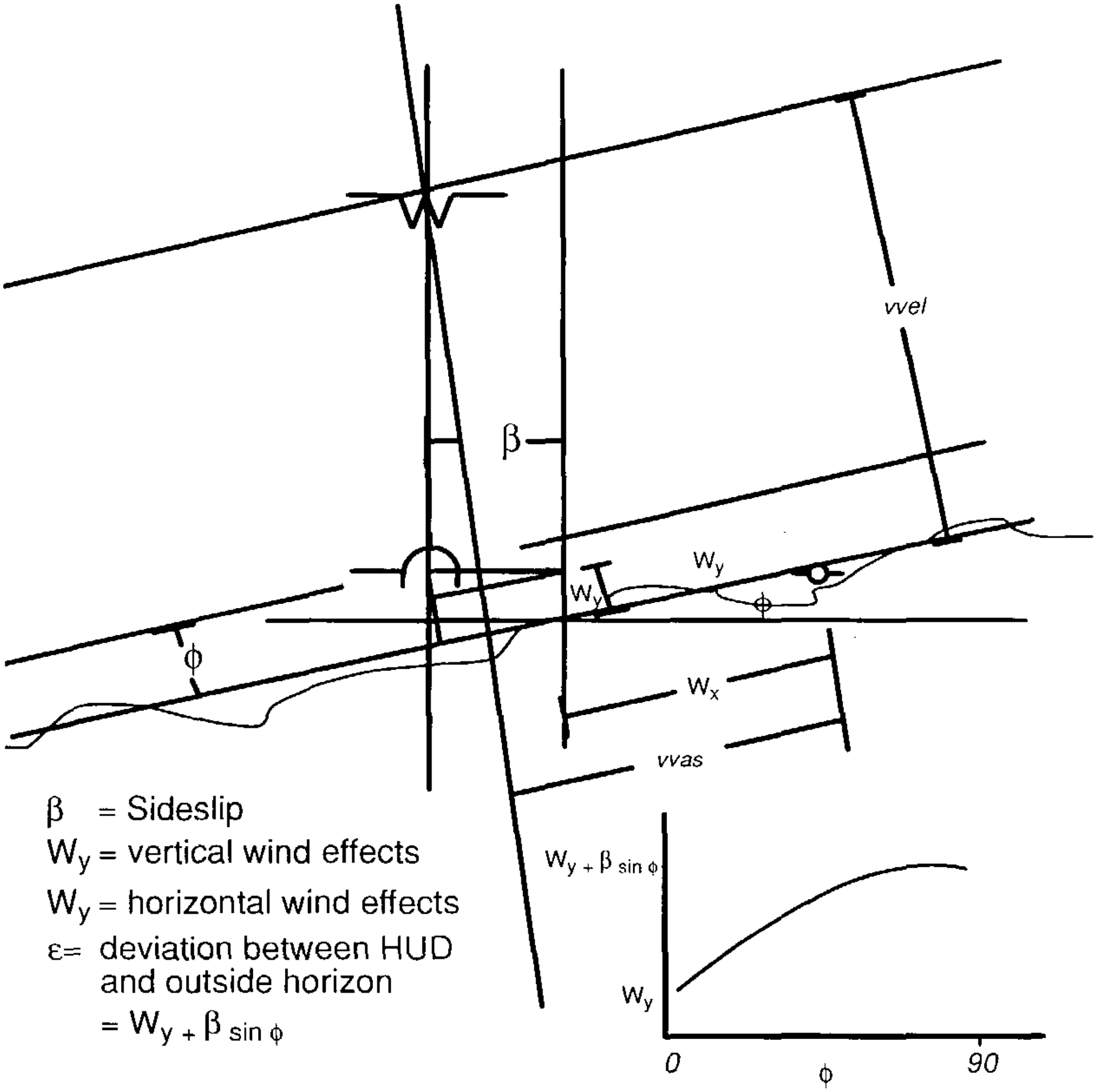


FIGURE 2. c. CDM caging mechanization.

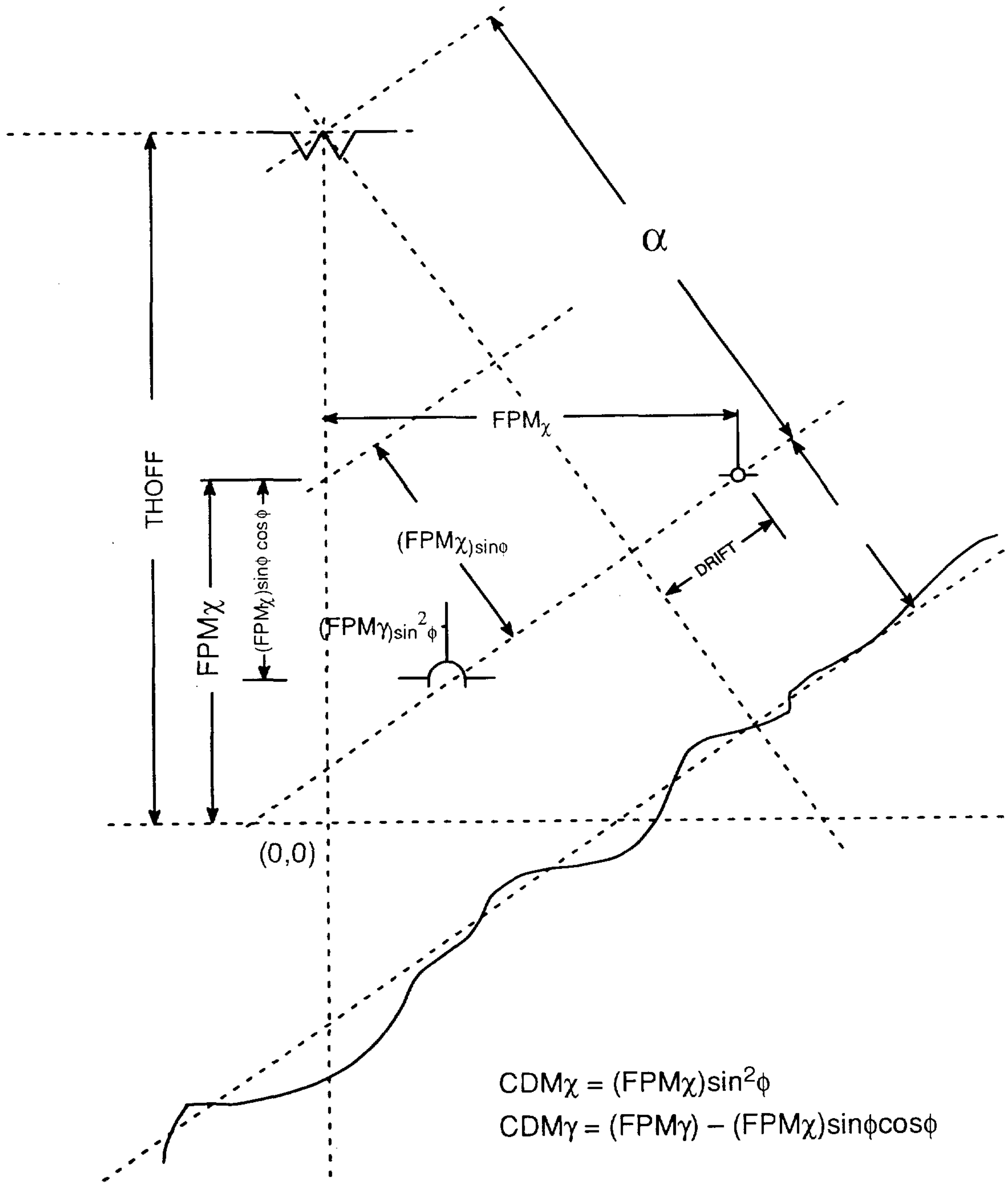


FIGURE 2. d. Alternative caging implementation

NOTE: It is sometimes desirable, if not required, to provide for a fully drifting FPM as the reference for the climb/dive scale. Specifically during weapons delivery and under some approach conditions, users have indicated that their center of reference should be the FPM as opposed to the CDM. Although this approach significantly increases the dynamics of the display, these limitations can be overcome by the reduced display clutter and workload resulting from eliminating the required cross-checking between the CDM and FPM during ground referenced flight. When the FPM is selected as the center of reference for the display, the FPM symbol should be presented as full size (i.e., 10 mr diameter circle, 10 mr wings, 5 mr tail).

REQUIREMENT LESSONS LEARNED (4.2.1.1)

4.2.1.2 Flight path marker. The flight path marker (FPM) (*Figure 3*) shall indicate the actual flight path of the aircraft when read against the outside world. The symbol shall be quickened and free to move within the limits of the HUD's total field of view (TFOV).

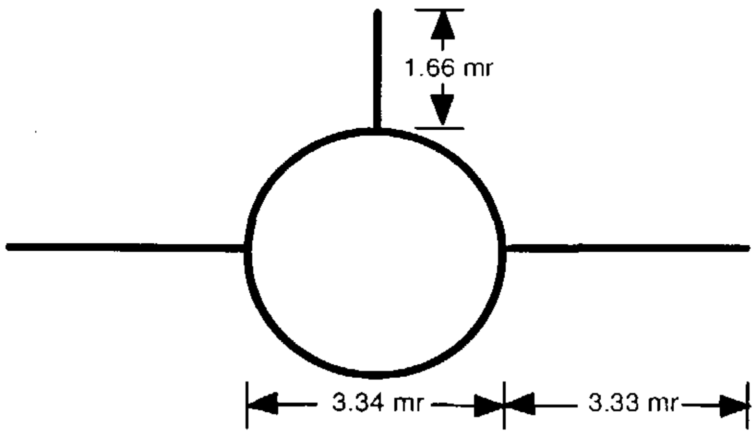


FIGURE 3. Flight path marker.

REQUIREMENT RATIONALE (4.2.1.2)

A major drawback to using a strictly caged CDM is the loss of correlation between the aircraft control reference and the outside visual scene. Pilots have found that, when using a free floating flight path marker, they could be assured the aircraft would fly toward the point on the ground the FPM overlaid. A compromise between display stability and conformality can be achieved by incorporating a CDM, to which the climb/dive ladder (i.e., pitch ladder) is referenced, and a velocity vector symbol that remains conformal to the outside visual scene.

When the FPM is displayed simultaneously with the CDM, it has proven necessary to reduce the FPM symbol to one-third the size of the CDM. Simulation trials discovered that using a full-size FPM with the CDM was far too distracting to the pilots, particularly during periods of shifting wind conditions.

REQUIREMENT GUIDANCE (4.2.1.2)

Because of the incorporation of the CDM as the aircraft control reference, the utility of the FPM is most likely to be limited to specific mission phases of flight where flight with reference to the ground or ground objects occurs, such as low-level navigation, terrain following, air-to-ground weapons delivery, and approach and landing during VMC, all of which require control of flight path relative to the ground.

REQUIREMENT LESSONS LEARNED (4.2.1.2)

4.2.1.3 Climb/dive ladder. The climb/dive ladder (CDL) shall display the aircraft's climb/dive and roll angle when read against the CDM. The CDL shall be a continuous scale consisting of the true and ghost horizon lines, climb/dive bars with numerical labels, and the zenith and nadir symbols. CAUTION: Pitch reference ladder horizon is no longer accurate to the real world.

4.2.1.3.1 Horizon line. The horizon line shall be incorporated into the CDL scale at the zero climb/dive angle position to provide a horizontal reference point. The horizon line shall be a bold line that extends the entire width of the HUD TFOV with a 32-mr gap in the center. The horizon line shall be occluded by the speed and altitude scales. The horizon line shall be displayed whenever it is within the limits of a circle defined by the IFOV. Otherwise, the ghost horizon line shall be displayed.

The ghost horizon line (GHL) shall provide a horizon reference any time the true horizon line is outside the limits of the IFOV. The GHL shall be presented as a bold, dashed line extending the entire width of the HUD TFOV. The line shall be positioned on the tangent of a circle about the center total field of view (CTFOV) and parallel to the horizon. Whenever the CDM is near the GHL, the radius of the circle shall be increased to maintain a minimum separation of 20 mr between the CDM and GHL.

4.2.1.3.2 Climb/dive bars. The climb/dive bars make up the CDL to display the aircraft's climb/dive angle when read against the CDM. The climb/dive bars shall consist of 11 solid climb bars and 11 dashed dive bars. The bars shall be positioned at 5-degree intervals from 5 to 30 degrees and at 10-degree intervals from 40 to 80 degrees.

To help distinguish between the climb and dive portions of the CDL, the wings on the dive bars shall be bent or sloped by one-half of the dive angle they represent.

4.2.1.3.2.1 Climb bars. The climb bars shall display the aircraft's climb angle when read against the CDM.

The climb bars shall consist of two 30-mr lines separated by a 32-mr gap with 5-mr vertical lines extending off each end. Numerical labels ranging from 5 to 80 shall indicate the degrees and shall be located on the lower left side of the respective climb bars (*Figure 4*).

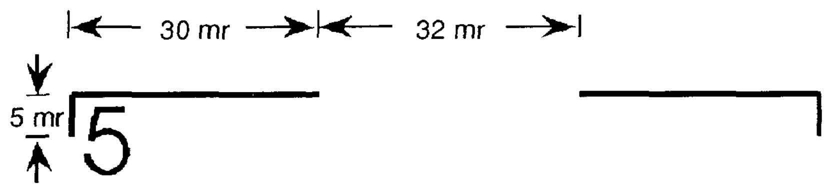


FIGURE 4. 5-degree climb bar.

4.2.1.3.2.2 Dive bars. The dive bars shall display the aircraft's dive angle when read against the CDM. The dive bars shall consist of two 30–mr dashed lines separated by a 32-mr gap. The bars shall be bent by one-half of the dive angle (e.g., the 40-degree dive bar has 20 degrees of slope). Numerical labels ranging from –5 to –80 shall be located on the upper left side of the respective dive bars (*Figures 5* and *6*).

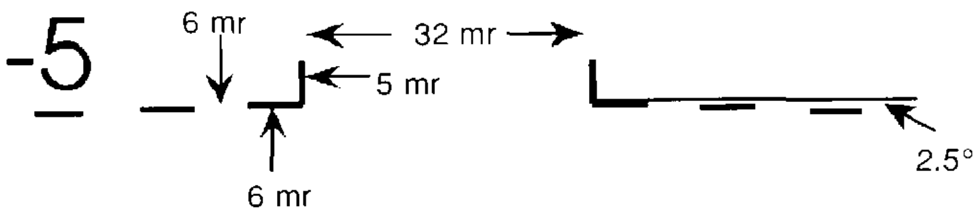


FIGURE 5. 5-degree dive bar.

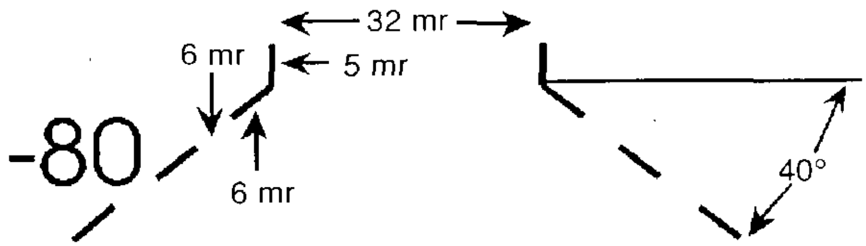


FIGURE 6. 80-degree dive bar.

4.2.1.3.3 Zenith symbol. The zenith symbol (*Figure 7*) shall display the highest possible climb angle (i.e., 90 degree climb angle). The zenith symbol shall always rotate to point toward the nearest horizon.

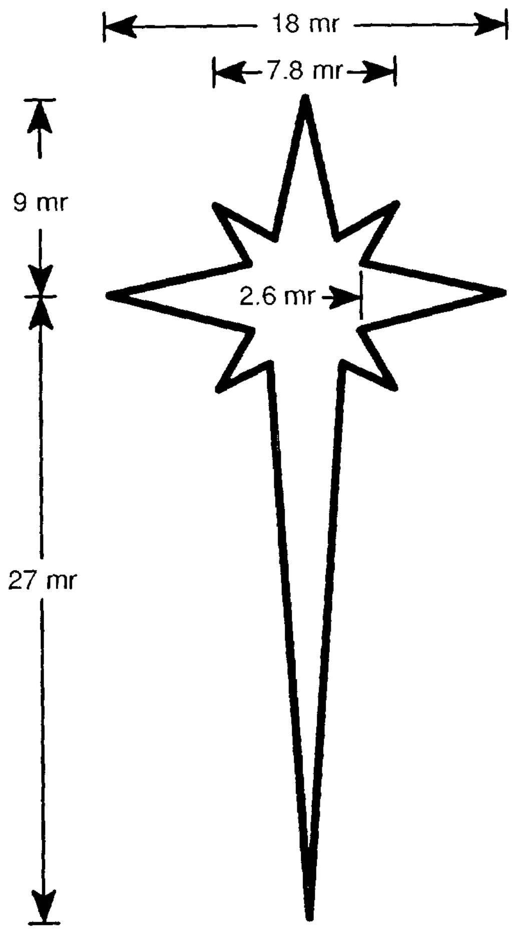


FIGURE 7. Zenith symbol.

4.2.1.3.4 Nadir symbol. The nadir symbol (*Figure 8*) shall represent the lowest possible dive angle (i.e., 90 degree dive angle). The nadir symbol is always rotated to point toward the nearest horizon.

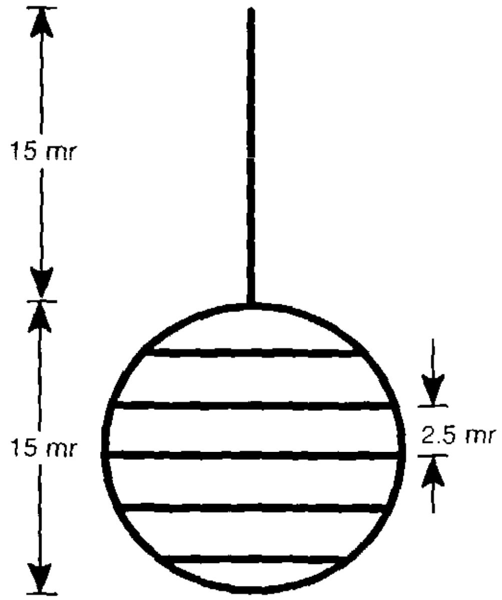


FIGURE 8. Nadir symbol.

REQUIREMENT RATIONALE (4.2.1.3)

Climb/dive ladder. Two other inherent problems with using the HUD as opposed to a conventional ADI as a primary source of attitude information are 1) the limited field of view of the HUD, and 2) the lack of contrast provided by the climb/dive ladder in representing positive and negative climb/dive angles. Ladder compression and formatting techniques were developed in an attempt to counter these inherent weaknesses.

Ladder compression. A conventional attitude director indicator (ADI) provides the pilot +/– 45 degrees of attitude reference on either side of the pitch reference symbol, some EADIs are capable of +/– 90 degrees. At best, current HUDs are capable of providing +/– 13 degrees of climb/dive reference. The effect is the same as if the pilot were looking at the ADI through a straw; at high pitch rates, the lines of the climb/dive ladder pass through the HUD FOV so fast that timely interpretation of aircraft attitude is nearly impossible.

In an attempt to slow down the rate at which the climb/dive ladder passed through the HUD, the ladder was compressed. Historically, the climb/dive ladder has been drawn conformal to the outside visual scene, meaning that the 10 degree line overlies a point 10 degrees above the horizon. The incorporation of compression, however, caused the ladder to lose conformality with the outside visual scene. In order to maintain conformality with the outside visual scene, the compression ratio of the ladder was mechanized to change as a function of climb/dive angle such that the ladder was not compressed, or 1:1 ratio with the outside visual scene, from 0 to +/–5 degrees and increased linearly to 4.4:1 ratio with the outside visual scene at the zenith and nadir. Therefore, the ladder remained conformal about the horizon, maintaining conformality during ground referenced flight such as approach and landing and low-level navigation, and compressed at larger climb/dive angles where outside correlation was not a high priority.

Ladder format. The second limitation of the HUD in providing sufficient attitude reference is its inherent lack of contrast between positive and negative climb/dive angles. In an attempt to maximize hemispheric asymmetry, several techniques have been adopted.

a) The most universally accepted technique is to dash the ladder lines in the lower hemisphere while the upper hemisphere lines remain solid.

b) A second technique adopted is bending the negative climb/dive ladder lines half the climb/dive angle the line represents (Example: the 20 degree climb/dive line should be articulated at a 10 degree angle relative to the horizon line). At higher climb/dive angles, the lines form a funnel pointing toward the horizon; this effect is enhanced by placing the horizon pointing tabs on the inside of the ladder lines. This technique not only provided asymmetry between hemispheres, but also gives the pilot a sense of relative magnitude of dive angle (e.g., the greater the articulation, the greater the dive angle).

The incorporation of the ladder articulation for the negative lines further enhances the asymmetry between nose up and nose down. In addition, the magnitude of bend provides a gross indication of the severity of dive angle.

Ladder Numbering. Traditionally, flight path ladders' numbers are placed on both sides of the ladder. This was required because the drift of the flight path marker often caused one side of the ladder to drift outside the FOV of the HUD or the lose of the ladder during high angle-of-attack banked maneuvers. When flying a quickened and caged CDM, the ladder does not drift away from the center of the HUD, thus the requirement to number both sides of the ladder is eliminated. Furthermore, placement of ladder numbers on only the left side of the ladder provides an additional cue to roll orientation: if the numbers appear on the right, the aircraft is inverted; if the numbers appear on the left, the aircraft is upright.

REQUIREMENT GUIDANCE (4.2.1.3)

The spacing of the CDL bars is compressed from a 1:1 ratio to a 4.4:1 ratio. The horizon line and the 5 degree climb/dive bar are spaced at a 1:1 relationship with the outside world. The compression ratio then increases linearly to a 4.4:1 ratio at the 90 degree zenith/nadir symbol. The following are the general equations used to position the climb bars, dive bars, and zenith and nadir symbols.

The first step is to find the equation that transforms the input angle x, of domain [5,90], to the proper compression ratio of the range [1,4.4].

$$m = \frac{4.4 - 1.0}{90 - 5} = \frac{3.4}{85}$$

$$\textit{Compression Ratio} = \frac{1}{m(x-5) + 1}$$

In order to find the distance from the horizon for the input angle x, we must add up all the compression ratios between the 5-degree bar and the input angle and add 5 for the distance from the horizon line to the 5 degree bar.

$$\textit{distance} = \int (\textit{Compression Ratio})\, dx + 5.0$$

$$\textit{distance} = \int \left(\frac{1}{m(x-5) + 1} \right) dx + 5.0$$

$$\textit{distance} = \frac{\ln [m\,(x-5) + 1]}{m} + 5.0$$

Although compression can result in a more readable display by reducing the degree of climb/dive scale motion, there are potential problems that may arise with a compressed scale. First, the incorporation of compression precludes the inclusion of a pitch reference in the display. Since one of the major advantages of the HUD is its use of a conformal display, it is impossible to deconflict the conformality of the pitch reference relative to the outside world, and pitch angle read against the climb/dive scale. Second, the incorporation of any kind of variable compression, whether step or linear, does not provide accurate pitch rate cues when read against the climb/dive scale. Pilots have reported that accurate pitch rate information is necessary during near stall recoveries and that any confusion in pitch rate can potentially create a hazardous condition. Designers should consider the importance of pitch rate information prior to incorporating any form of climb/dive scale compression.

REQUIREMENT LESSONS LEARNED (4.2.1.3)

Alternative forms of compression have been used in the past; some, with less than optimum results. The F-16 Block 40 HUD symbology was implemented such that the climb/dive ladder was compressed 2:1 above 60 degrees and below -60 degrees. The rationale was that conformality was not a priority above 60 or below -60 degrees. However, a problem arose when a pilot, whose FPM was depressed such that its position was outside the IFOV of the HUD, transitioned from the FPM to the gun cross to acquire attitude information. The ladder, while still referenced to the FPM, read nearly 90 degrees against the gun cross. However, the aircraft's pitch attitude was not 90 degrees as the gun cross indicated but rather 75 degrees. This inconsistency was a direct result of the implementation of the 2:1 compression above 60 degrees.

Therefore, under conditions in which compression is implemented and the climb/dive ladder remains referenced to the CDM, a pitch reference should not be displayed. Using the CDM should not be a problem, however, because the mechanization is such that the control reference should never leave the IFOV requiring the pilot to transition to a pitch reference.

4.2.1.4 Longitudinal acceleration cue. The longitudinal acceleration cue (LAC), when read against the CDM, shall provide an indication of the aircraft's acceleration along its flight path (*Figure 9*).

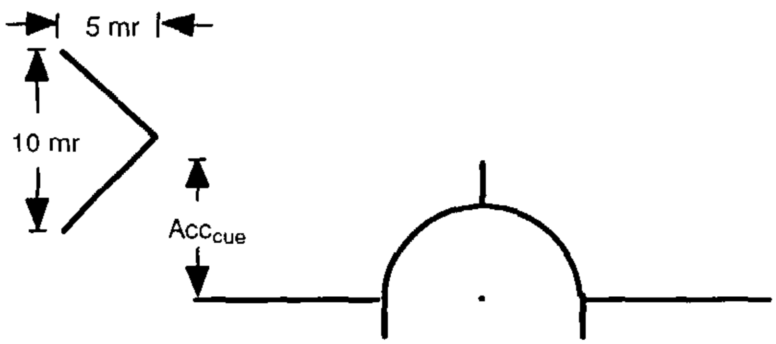


FIGURE 9. Longitudinal acceleration cue.

REQUIREMENT RATIONALE (4.2.1.4)

Although this symbol is not essential, it reduces workload in a variety of ways:

a. Shows if aircraft is accelerating or decelerating so changes in airspeed can be made smoothly. It provides lead information when approaching a new airspeed.

b. Can be used as a potential flight path in that it represents the achievable climb or dive angle while maintaining constant airspeed and power setting.

c. Energy indicator: if the cue is above the horizon, the aircraft is gaining total energy; below the horizon, the aircraft is losing total energy.

d. Regarded as a throttle command, it shows which way to move the throttle to stabilize at your current climb rate.

e. Useful for detection and escape of wind shear.

REQUIREMENT GUIDANCE (4.2.1.4)

This symbol is normally displayed in landing modes. It is also useful in refueling tasks and other modes where a command airspeed is being flown. The following set of equations describes a nominal mechanization of the LAC. Based on aircraft response to changes in throttle setting, alternative scaling factors may be necessary.

Acc = Aircraft's Longitudinal Acceleration in G's
Acc_{cue} = Longitudinal Acceleration Cue Position
$Acc_{cue} = Acc \times 9.0 \quad \lim[-4.5, 4.5]$

REQUIREMENT LESSONS LEARNED (4.2.1.4)

4.2.1.5 Speed worm. The speed worm (*Figure 10*) shall indicate deviation from the aircraft's on-speed angle of attack. This symbol shall be located on the left wing of the CDM and remain vertical in relation to the CDM. The worm is a rectangle that varies in height above or below the CDM wing. The speed worm shall be displayed when the HUD is in instrument landing system (ILS) mode or landing gear is down.

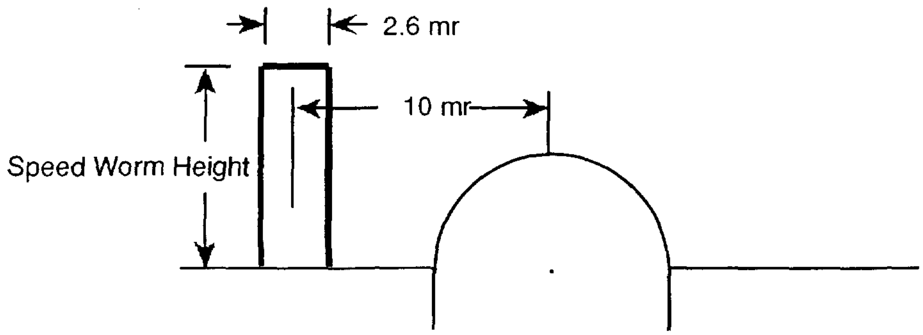


FIGURE 10. Speed worm.

REQUIREMENT RATIONALE (4.2.1.5)

Angle-of-attack error is a pitch-related variable that indicates the deviation of the current AOA from a desired value and is vertically oriented to be compatible with real-world coordinates and control motion. It is normally placed on the left half of the display near the left wing of the aircraft symbol. This location is chosen for several reasons. For landing, angle-of-attack is used to control speed. Location on the left is consistent with the general scheme of putting airspeed on the left, altitude on the right. Location on the left half of the display is also in agreement with the standard arrangement of separate cockpit instruments in Navy aircraft, where the apexer is situated on the left side of the instrument panel.

REQUIREMENT GUIDANCE (4.2.1.5)

The following set of equations describes the mechanization of the Speed Worm.

α *spd* = On Speed Angle of Attack
α = Aircraft's Angle of Attack
b = Scaling Factor
Speed Worm Height = $\alpha\ spd - \alpha \times b$ lim [–1.0, 1.0]

Scaling of the speed worm depends on the dynamic qualities of the specific aircraft. Fighter/attack aircraft, for example, in which AOA can change rather rapidly, is likely to have a relatively low scaling factor (e.g., 0.25); whereas, a less dynamic airframe in which changes in AOA are less dramatic may implement a higher scale factor (e.g., 1.0). In either case, the selection of scaling factor should be made based on trials in a high fidelity aero-model simulation facility.

REQUIREMENT LESSONS LEARNED (4.2.1.5)

4.2.1.6 Aircraft pitch reference symbol. The pitch reference symbol (also known as the miniature aircraft symbol) shall be in a fixed location on the display, referenced to the aircraft fuselage datum. The apex of the W shall be aligned with the wings and the symbol shall be laterally centered. Occlusion priority is high. (*Figure 11*)

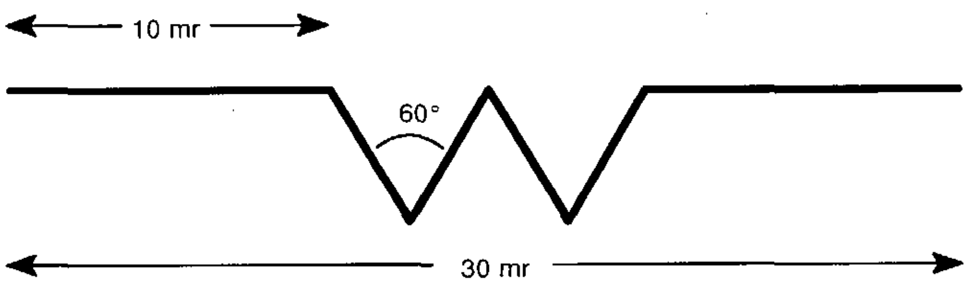


FIGURE 11. Aircraft pitch reference.

REQUIREMENT RATIONALE (4.2.1.6)

The aircraft pitch reference symbol has three primary functions: (1) a pointer function for attitude reference and angle of attack; (2) a center dot or apex which constitutes a fixed display center reference point, null reference point, and index mark; and (3) a positive reference of bank angle. The angle of the symbol is normally 60 degrees and it can be referenced to the flight path angle display to give a positive bank angle reference. This is one of the functions of the equivalent symbol on an attitude director indicator (ADI). The symbol has pictorial qualities, that is, wings and wheels, which provide vertical orientation cues against a dynamic background.

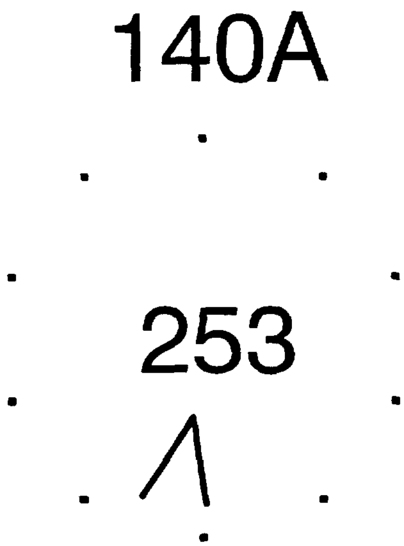
REQUIREMENT GUIDANCE (4.2.1.6)

The pitch reference symbol is located at one of three points which are usually near the top of the display. On previous aircraft, it has been located at the fuselage datum (aircraft reference line or waterline) on several aircraft, at the gun aim point (F–16), or at the zero lift line. The zero lift line and gun aim point are preferred because they provide more useful information to the pilot. Although the gun cross symbol is not recommended for use as an attitude reference, it has been used in place of the standard pitch reference because it creates less clutter.

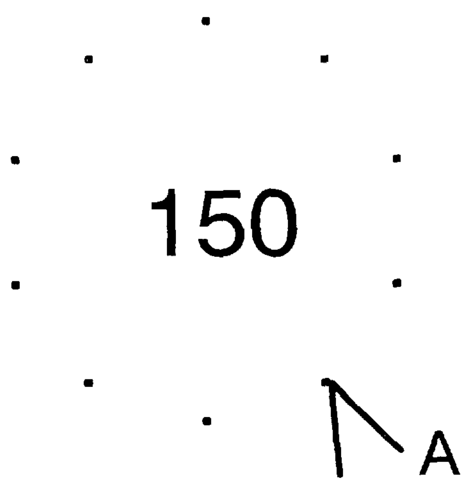
4.2.2 Scales. Scales shall be used to display the aircraft's speed, barometric altitude, heading, and roll. All scales, except the roll scale, shall be positioned against the left- and right-hand reference points (LHRP and RHRP). The roll scale shall be centered around the CTFOV.

4.2.2.1 Airspeed scale. The speed scale (*Figure 12*) shall display the aircraft's current and commanded speeds. The speed scale shall consist of a dial with index, commanded speed caret, and various readouts. The readouts shall include the current speed and appropriate commanded speeds. The center of the speed dial shall be positioned at the LHRP. The type of airspeed displayed (indicated or calibrated) shall be that which the aircraft is normally flown and shall not include any associated letters. This display shall be presented full time on the primary flight reference (PFR).

The current speed shall be displayed as a digital readout at the center of the dial. The commanded speed readouts shall be displayed above the dial whenever the difference between the current speed and the commanded speed is greater than 40 knots. The commanded speed caret shall be displayed on the dial whenever the aircraft's speed is within 40 knots of the commanded speed.



a. **Current and commanded speeds displayed.**



b. **Current speed and commanded speed caret displayed.**

FIGURE 12. Airspeed scale.

4.2.2.1.1 Airspeed dial. The speed dial (*Figure 13*) shall consist of 10 dots equally spaced around an 18-mr circle with a 7-mr index located 9 mr from the center of the dial. The index shall make one complete clockwise revolution for every 100 knots of increasing speed. The center of the speed dial shall be positioned at the LHRP.

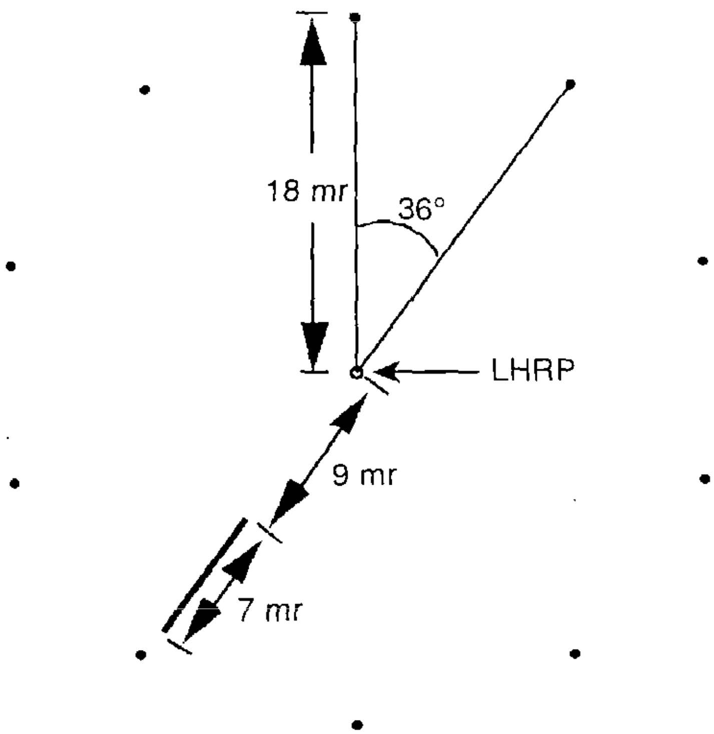


FIGURE 13. Speed dial.

4.2.2.1.2 *Airspeed readout.* The speed readout, composed of three digits, shall be displayed in the center of the speed dial. All digits shall be full size (7 mr high by 4 mr wide), and leading zeroes shall be displayed as blank spaces. The resolution of the display shall be to the nearest knot.

999

4.2.2.1.3 Commanded speed caret. The commanded speed caret (*Figure 14*) shall point to the commanded speed whenever the difference between the current speed and the commanded speed is less than 40 knots. The caret shall be located on the outside edge of the speed dial pointing inward.

A 60 percent sized letter shall appear next to the caret to identify which commanded speed is being indicated by the caret.

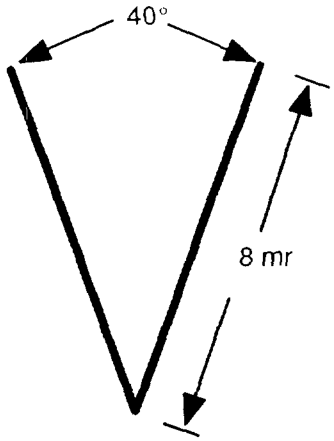


FIGURE 14. Commanded speed caret.

4.2.2.1.4 Commanded speed readouts. The commanded speed readouts shall display the various commanded speeds. A readout shall be displayed whenever the difference between the current speed and the commanded speed is greater than 40 knots. The readout shall be positioned above the speed dial, followed by its letter identifier, and shall be 60 percent of full size.

140 A

REQUIREMENT RATIONALE (4.2.2.1)

Standard instrument practice calls for altitude on the right and airspeed on the left; this permits horizontally oriented heading and roll scales to be placed on the top or bottom of the display (JANAIR Rpt. 680505).

Several organizations within the DOD have evaluated the relative merits of the counter-pointer format under control/simulator conditions. These evaluations indicated that the counter pointer format significantly enhanced pilot performance when compared with conventional vertical tape and pure digital presentation.

The relative merits of the counter-pointer format are as follows:

a. It takes up less space (causing less clutter) than the vertical scale.

b. The moving tape-fixed pointer scale is inherently harder to read because the numbers are moving and not always in the same place.

c. There is some evidence that the scales might be interpreted as horizontal pitch lines when viewed by a disoriented pilot in a 90-degree bank.

d. The dial format provides trend information clearly, with no confusion about direction (clockwise is more), and is directly analogous to the round dials pilots learn to fly with.

e. During extremely rapid descents, rate and direction of movement of vertical tape scales can be hard to distinguish.

REQUIREMENT GUIDANCE (4.2.2.1)

Scales are normally positioned with at least ten degrees lateral separation between the altitude and airspeed. However, they must be within the instantaneous FOV and too much lateral separation can increase cross-check scan time.

The following identifiers are recommended for command airspeeds: 1 = First reference speed during takeoff, (i.e., V ref); 2 = Second reference speed during takeoff; R = Rotate speed; F = Flap retract/extend speed; G = Gear retract/extend speed. When a reference speed has passed and is no longer of use, it should be removed from the display.

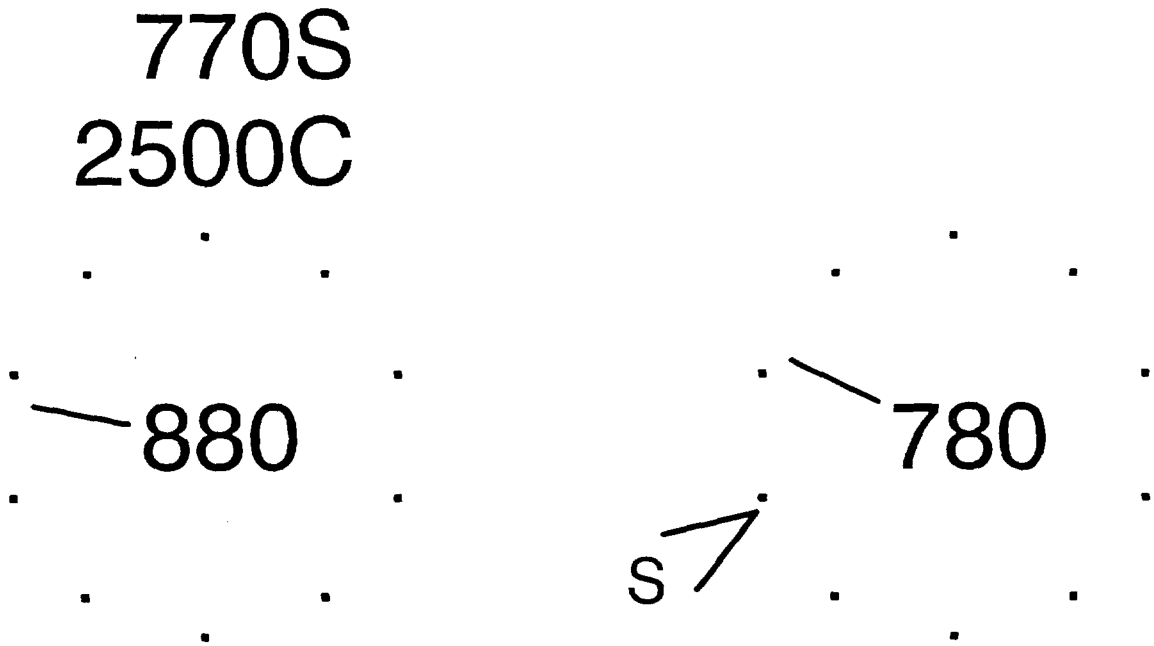
During up-and-away flight, positioning of the airspeed scale should correspond to the vertical location of the CDM. During approach and landing, the CDM is likely to drop significantly within the field of view of the HUD as a result of the increase in angle-of-attack. To maintain a minimal cross-check distance between the CDM and the airspeed scale, the scale should drop within the FOV of the HUD to correspond to the new, stabilized position of the CDM. This is particularly important for fighter/attack aircraft which tend to fly approaches at higher angles of attack.

Care should be given as to how this change in position is accomplished, as abrupt changes in scale location may be disturbing to pilots. With the incorporation of quickened CDM, which greatly stabilizes the reference within the IFOV of the HUD, it may be possible to allow the airspeed and altitude scales to move vertically with the CDM.

REQUIREMENT LESSONS LEARNED (4.2.2.1)

Recent research by the Royal Air Force and USAF has concluded that removal of the dots, which results in a reduction in display clutter, does not degrade pilot performance. However, concern remains that removal of the scale dots may result in a reduction in precision when command airspeeds are required. This issue remains unresolved.

4.2.2.2 **Altitude scale.** The altitude scale (*Figure 15*) shall display the aircraft's current and commanded altitudes and the aircraft's vertical velocity. The altitude scale shall consist of a dial with an index, an altitude readout, a commanded altitude caret, commanded altitude readouts, and a vertical velocity arc. The commanded altitude caret shall be displayed whenever the aircraft's altitude is within 400 ft of the commanded altitude, and the vertical velocity arc is displayed whenever the CDM is limited. The altitude dial shall be positioned at the RHRP.



a. Current and commanded altitudes and vertical velocity arc displayed; CDM limited.

b. Current altitude and commanded altitude caret displayed.

FIGURE 15. Altitude scale.

4.2.2.2.1 Altitude dial. The altitude dial (*Figure 16*) shall consist of 10 bold dots equally spaced around a 25-mr circle and a 10.5-mr index located 12.5 mr from the center of the dial. The index shall make one complete clockwise revolution for every 1000 feet of increased altitude. The center of the dial shall be located at the RHRP.

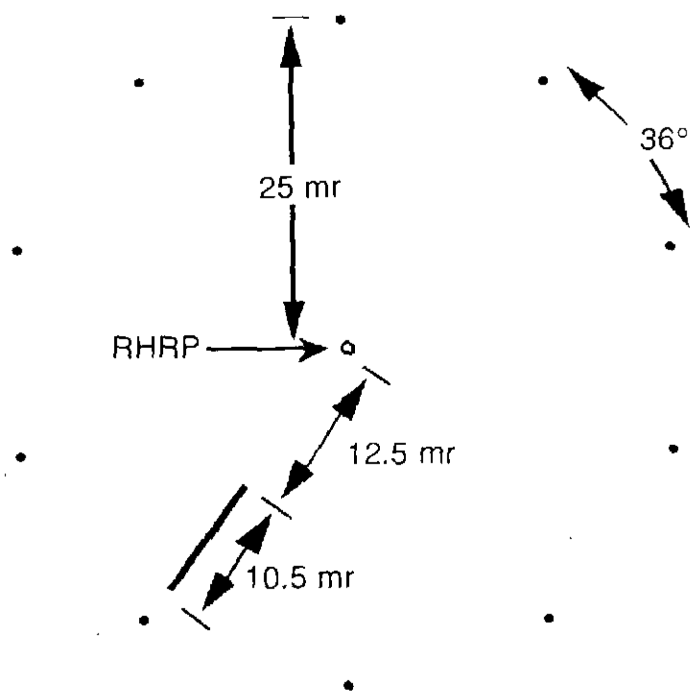


FIGURE 16. Altitude dial.

4.2.2.2.2 Altitude readout. The altitude readout, composed of five digits, shall be displayed at the center of the altitude dial. Whenever the aircraft's altitude is greater than or equal to 10,000 ft, the two leading digits (thousands) shall be displayed full size (7 mr high by 4 mr wide) and the remaining three digits (hundreds, tens and units) shall be displayed at 60 percent of full size. The resolution of the display shall be to the nearest hundred feet.

10000

When the aircraft's altitude is less than 10,000 ft, all the digits shall be displayed full size. Leading zeroes shall be displayed as blank spaces. The resolution of the display shall be to the nearest ten feet.

9870

4.2.2.2.3 Commanded altitude caret. The commanded altitude caret (*Figure 17*) shall point to the commanded altitude whenever the difference between the current altitude and the commanded altitude is less than 400 feet. The caret shall be located on the outside edge of the altitude dial pointing inward.

A 60 percent sized letter shall appear next to the caret to identify which commanded altitude is being indicated by the caret.

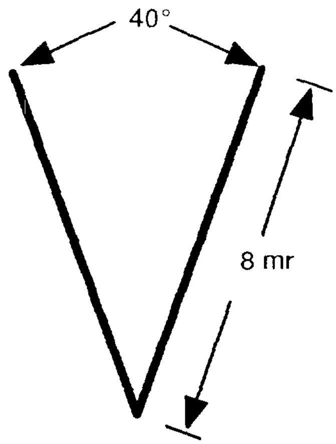


FIGURE 17. Commanded altitude caret.

4.2.2.2.4 Commanded altitude readouts. The commanded altitude readouts shall display the various commanded altitudes. A readout shall be displayed whenever the difference between the current altitude and a commanded altitude is greater than 400 feet. The readouts shall be positioned above the altitude dial.

All digits shall be 60 percent of full size with leading zeros displayed as blank spaces. The resolution of the display shall be to the nearest foot. The last readout shall be positioned 40 mr above and 10 mr left of the RHRP. Preceding readouts shall be positioned at 10-mr increments above their following readouts.

1500 S

600 D

REQUIREMENT LESSONS LEARNED (4.2.2.2)

A low altitude, high speed aircraft might use a fixed scale, moving index display for radar altitude. Such a configuration is being used in the Low Altitude Navigation Targeting Infrared for Night (LANTIRN) program. In this case, it is the moving index, usually a thermometer type index, that provides the trend information along with being able to associate positions on the scale with specific ground clearance levels. The limited range of a fixed scale is acceptable for display of radar altitude in low-level (terrain following—TF) flight and allows the fastest interpretation of critical ground clearance.

4.2.2.2.5 Vertical velocity arc. The vertical velocity arc (*Figure 18*) shall display the aircraft's vertical velocity when read against the altitude dial. The vertical velocity arc shall be a bold arc that is displayed whenever the CDM is limited. During a climb, the amount of vertical velocity shall be displayed by a bold arc that starts at the 9 o'clock position (750 ft) and extends in the clockwise direction along the upper arc of the altitude dial. During a dive, it shall extend in the counter-clockwise direction along the lower arc.

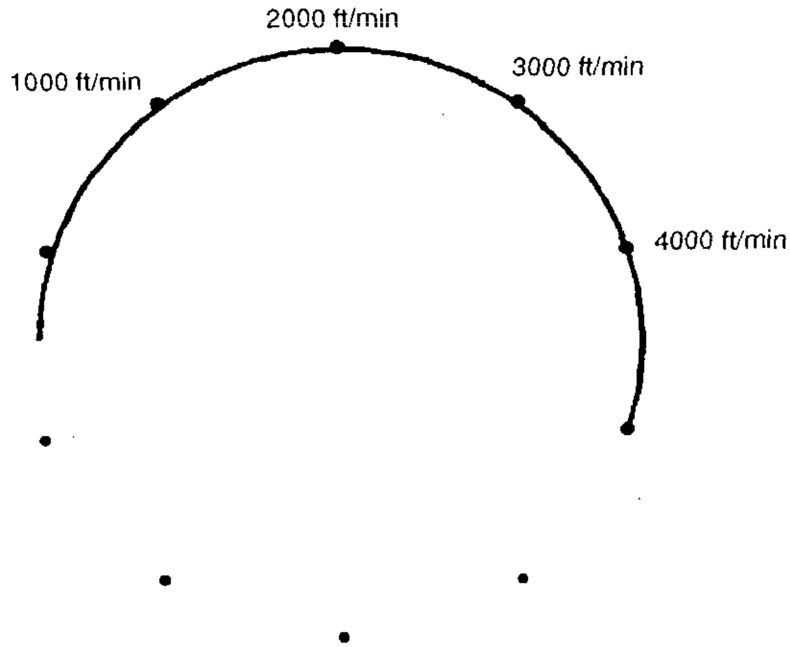


FIGURE 18. Vertical velocity arc.

In addition to the vertical velocity trend information, it is recommended that a digital readout of vertical velocity also be presented just below the altitude scale.

VV–1500

REQUIREMENT GUIDANCE (4.2.2.2.5)

The following chart shows how far the vertical velocity arc extends around the altitude dial for a given climb rate. The arc starts at the 9 o'clock position and is drawn in the clockwise (CW) direction.

Climb Rate	**Altitude Dial Position (CW direction)**
Level Flight	750 ft (9 o'clock)
1000 ft/min	900 ft dot
2000 ft/min	0 ft dot
3000 ft/min	100 ft dot
4000 ft/min	200 ft dot

The following chart shows how far the vertical velocity arc extends around the altitude dial for a given dive rate. The arc starts at the 9 o'clock position and is drawn in the counter-clockwise (CCW) direction.

Dive Rate	**Altitude Dial Position (CCW direction)**
Level Flight	750 ft (9 o'clock)
1000 ft/min	600 ft dot
2000 ft/min	500 ft dot
3000 ft/min	400 ft dot
4000 ft/min	300 ft dot

REQUIREMENT LESSONS LEARNED (4.2.2.2.5)

4.2.2.3 Heading scale. The heading scale (*Figure 19*) shall indicate the aircraft's magnetic heading and shall consist of a horizontal scale and a lubber line. The lubber line shall indicate the aircraft's magnetic heading when read against the horizontal scale. The center point of the heading scale shall be located above the midpoint of a line connecting the LHRP and RHRP.

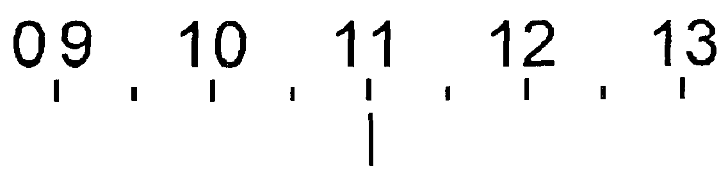


FIGURE 19. Heading scale.

4.2.2.3.1 Horizontal heading scale. The horizontal heading scale (*Figure 20*) shall be a continuous scale that moves left and right indicating aircraft heading when read against fixed lubber line. The scale shall consist of 5-mr, vertical tic marks every 10 degrees and 3-mr, vertical tic marks every 5 degrees. A minimum of 30 degrees shall be displayed and the scale compressed at a 5:1 ratio. Two-digit numeric labels that range from 01 to 36 shall be positioned above the 10-degree tic marks indicating 10 to 360 degrees of heading.

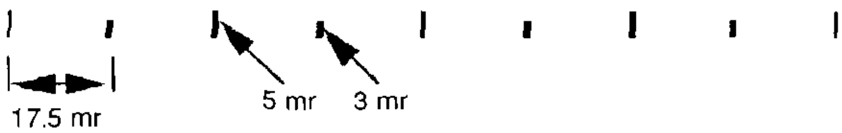


FIGURE 20. Horizontal heading scale.

REQUIREMENT GUIDANCE (4.2.2.3.1)

Heading is always displayed in degrees with tick marks usually every 5 degrees. Two-digit numerics are displayed with a longer tick mark every 10 degrees. A minimum of three sets of numerics should always be displayed either above the tick marks when displayed at the top of the HUD, or below the tick marks when displayed at the bottom of the HUD. The heading scale on the HUD need not conform with the outside world; in fact, a compressed scale of 5:1 ratio is preferred. Such a compression ratio provides sufficient scale coverage without cluttering the display. If a digital readout is considered, it should be as an addition to the scale or as a declutter option.

4.2.2.4 Bank scale. The bank scale (*Figure 21*) shall display the aircraft's bank and sideslip. The bank scale shall consist of a curved bank scale drawn around the CTFOV and a bank/sideslip pointer.

FIGURE 21. Bank scale with 20° right bank.

4.2.2.4.1 Curved bank scale. The curved bank scale (*Figure 22*) shall consist of a center index and three tic marks at 10-degree intervals on either side of the index representing 10, 20, and 30 degrees of aircraft bank. When the aircraft's bank angle is greater than 25 degrees, additional tic marks shall be displayed at the 45-degree and 60-degree positions on the same side of the scale as the bank/sideslip pointer. Likewise, when the bank angle is greater than 55 degrees, additional tic marks shall be drawn at the 90-degree and 135-degree positions.

The radius of the bank scale shall be centered about the CTFOV. If the CDM comes within 20 mr of the zero bank index, the bank scale shall be lowered to maintain the 20-mr separation between the CDM and the scale.

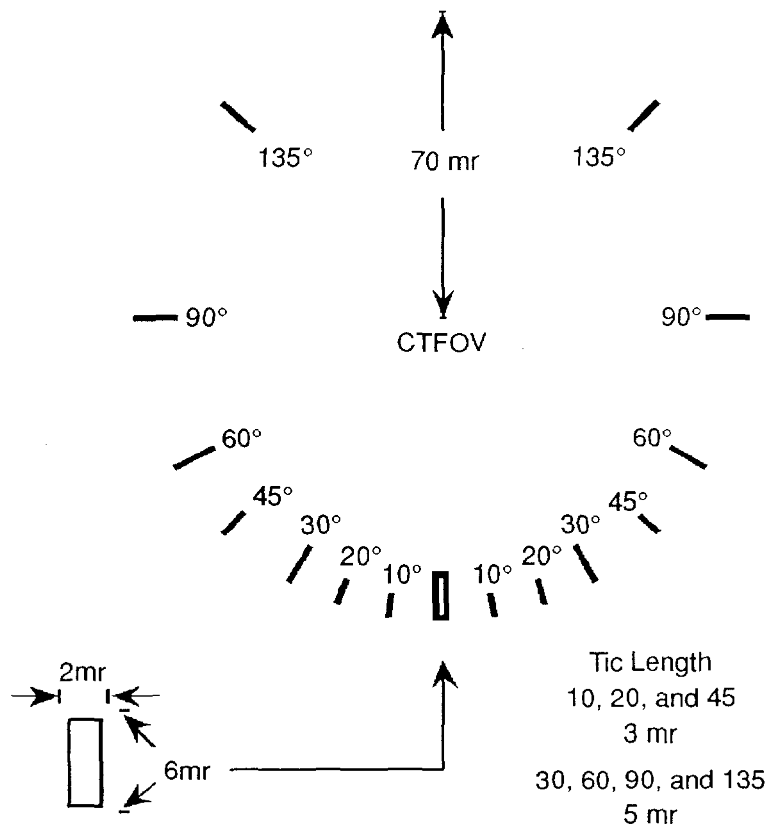


FIGURE 22. Curved bank scale.

4.2.2.4.2 Bank/sideslip pointer. The bank/sideslip pointer (*Figure 23*) shall be divided into two sections: a triangle shaped upper section and a trapezoid shaped lower section. The upper section shall indicate the magnitude and direction of roll when read against the curved bank scale. The lower section shall indicate the magnitude and direction of aircraft sideslip when read against the upper section.

When the aircraft is at wings-level flight, the bank/sideslip pointer shall be positioned below the center index of the curved bank scale with the tip of the pointer touching the bottom of the center index of the scale. As the aircraft banks in the clockwise direction (right wing down), the pointer shall move an equal number of degrees around the curved scale in the counter-clockwise direction; likewise for a left wing down bank. The pointer has unlimited 360-degree movement about the CTFOV and is rotated for all bank angles to point toward the CTFOV.

The lower section shall be positioned relative to the upper section by the amount of sideslip. For example, with 30 degrees of right bank and a sideslip of 3 degrees to the right, the upper section is rotated to the 30-degree tic and the lower section is rotated 33 degrees.

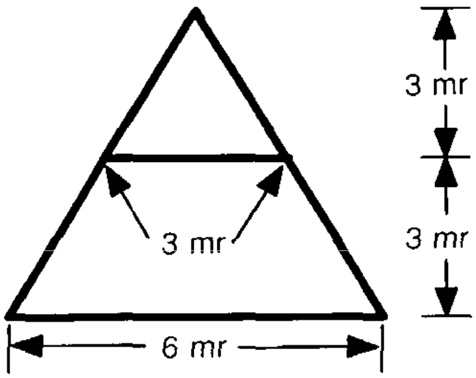


FIGURE 23. Bank/sideslip pointer.

4.2.3 Navigational symbology. The navigational symbology shall provide the pilot with location and steering information to return to a designated flight path or course. The symbology shall consist of a course deviation indicator (CDI), flight director steering bars, and a tactical air navigation (TACAN) indicator. The CDI, VDI, and steering bars shall be positioned relative to the CDM. The TACAN indicator shall be positioned relative to the CTFOV.

4.2.3.1 Course deviation indicator (CDI). *The course deviation indicator (Figure 24) shall display the selected course and the magnitude and direction of deviation. The indicator shall be centered around the CDM and shall consist of a scale and a pointer. A numerical readout of the selected course should be provided on the display.*

The scale shall consist of four dots with a maximum of 2 dots being displayed at any one time. The pointer shall be read against the CDM and CDI scale. The pointer and scale shall rotate about the CDM to indicate the selected course.

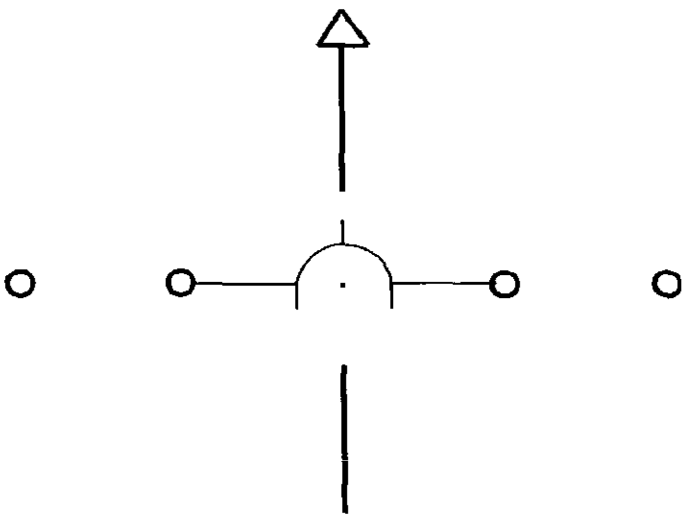


FIGURE 24. Course deviation indicator.

4.2.3.1.1 CDI scale. The CDI scale (*Figure 25*) shall contain four 3-mr circles, or dots, with a maximum of two dots being displayed at any instance. On either side of the scale, the inner two dots shall be located 15 mr from the center and each outer dot located another 15 mr from the inner dot. The CDI scale shall be centered upon the CDM and shall be free to rotate a full 360 degrees about the CDM.

When the deviation is more than one and one–half dots, two dots shall be shown on the same side of the CDM as the CDI pointer. When the deviation is between one–half and one and one–half dots, the inner two dots on each side of the CDM shall be shown. No dots shall be shown when the deviation is less than one–half dot.

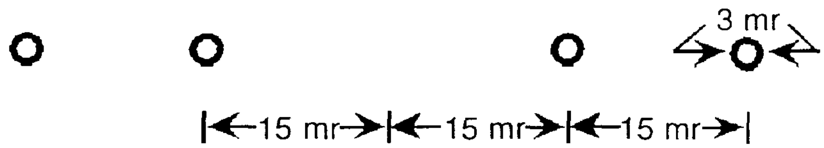


FIGURE 25. CDI scale.

4.2.3.1.2 CDI pointer. The CDI pointer (*Figure 26*) shall indicate course deviation when read against the CDI scale.

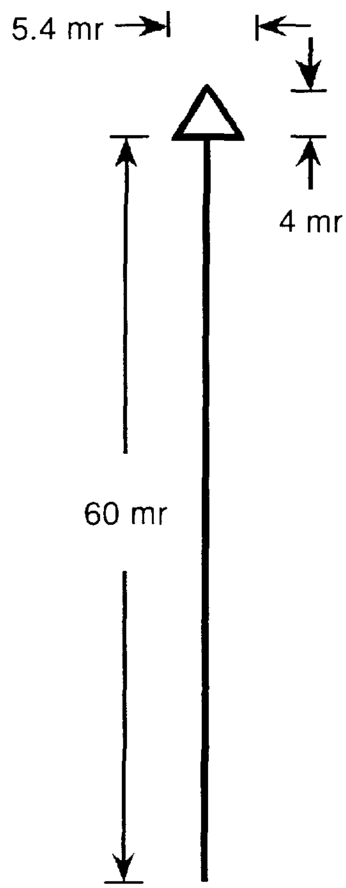


FIGURE 26. CDI pointer.

REQUIREMENT RATIONALE (4.2.3.1)

The CDI presented here is a direct translation of traditional course deviation Indicator and course arrow which have been part of head-down horizontal situation indicators (HSIs) for decades. In this case, the CDI and the course arrow have been combined into a single symbol. One advantage of this type of implementation over other symbology, such as the glideslope and localizer deviation bars used in the F–16 for ILS raw data, is that the CDI provides not only lateral deviation but also angular deviation. Pilots have found this type of implementation to be a benefit, particularly during course intercept maneuvers.

REQUIREMENT LESSONS LEARNED (4.2.3.1)

4.2.3.2 Vertical deviation indicator (VDI). The vertical deviation indicator (VDI) (*Figure 27*) shall display the magnitude and direction of the aircraft's vertical deviation from the desired glidepath.

The indicator shall consist of a scale and a pointer. The pointer shall be read against the scale. For ILS glideslope, one dot of pointer deflection represents 0.35 degrees of glideslope deviation.

The VDI shall be located to the right of the CDM and shall move vertically with it.

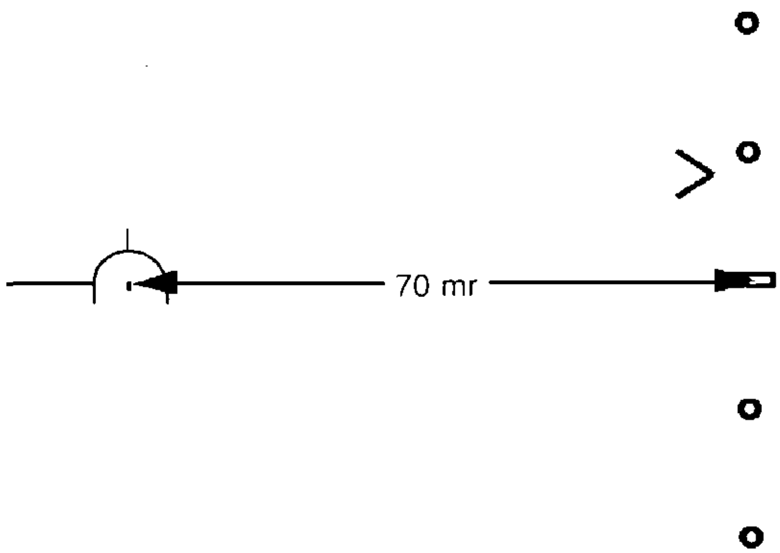


FIGURE 27. Vertical deviation indicator.

4.2.3.2.1 VDI scale. The VDI scale (*Figure 28*) shall be used in conjunction with the VDI pointer to *indicate* vertical deviation. The scale shall consist of four 3-mr circles, or dots, and a 6-mr by 2-mr, open-centered box. The dots shall be located two above and two below the box.

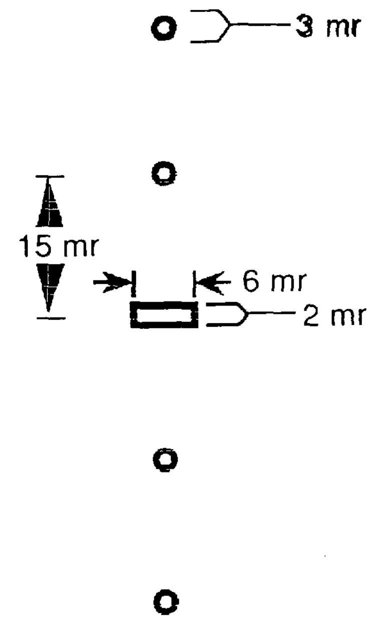


FIGURE 28. VDI scale.

4.2.3.2.2 VDI pointer. The vertical deviation pointer (*Figure 29*) shall indicate vertical deviation when read against the VDI scale. The pointer shall be located on the left side of the VDI scale pointing to the right.

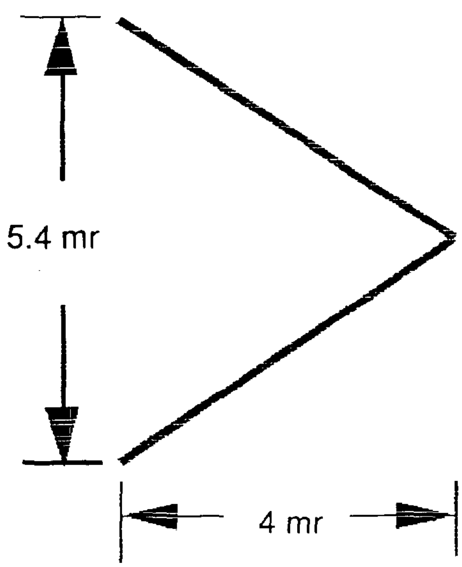


FIGURE 29. VDI pointer.

REQUIREMENT LESSONS LEARNED (4.2.3.2)

This vertical deviation indicator is a direct translation of the vertical deviation indicator used in head-down ADIs. One significant difference is the placement of the indicator on the right side of the display. This change was made as a means of minimizing cross-check differences between this indicator and the altitude indicator.

4.2.3.3 Flight director steering bars. *The two flight director steering bars, bank steering and pitch steering (Figure 30),* shall indicate the amount and direction of the flight director roll and pitch steering error, respectively, when read against the CDM. As the pilot rolls and pitches in the direction of the bars, the steering errors decrease and the bars move toward the CDM. The aircraft is at the commanded roll and pitch angles when the bars are positioned on the CDM. Both bars shall be 80 mr in length and displayed whenever the HUD is in ILS mode. The movement of the bars shall be limited to 2.5 degrees.

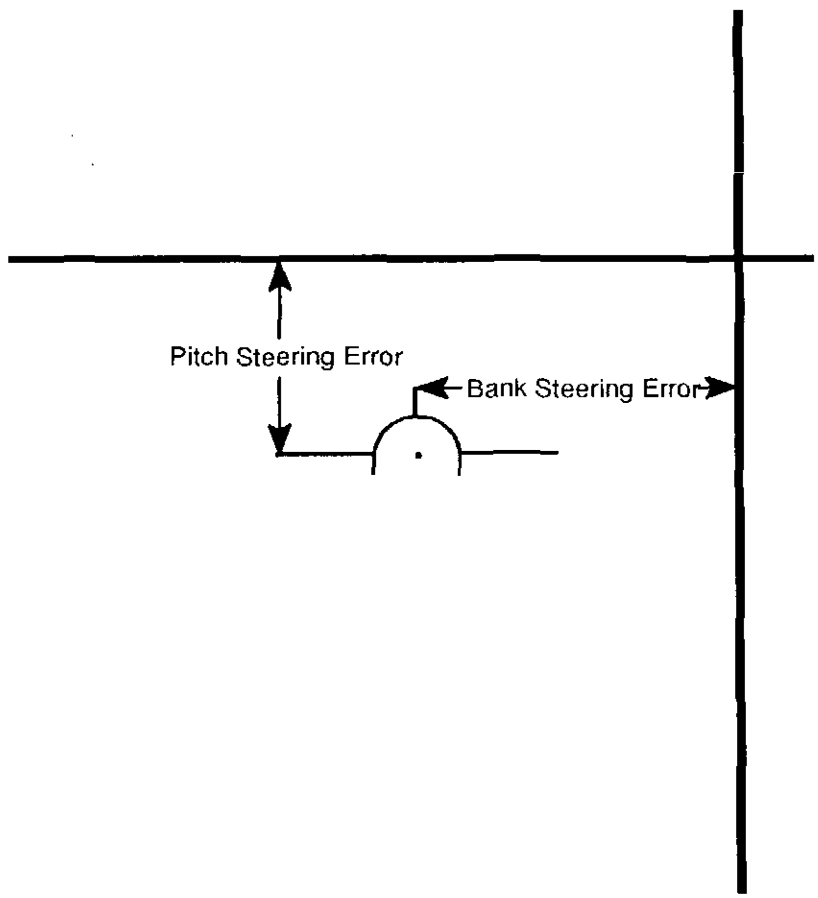


FIGURE 30. Flight director steering bars.

REQUIREMENT RATIONALE (4.2.3.3)

The use of a flight director in increasing approach and landing accuracy is well documented. The major question is the best manner in which to display the information to the pilot. Two alternative formats seem to predominate in current aircraft: the single cue flight director, and the dual cue flight director. The single cue format combines the pitch and bank steering command into one symbol such that the pilot "steers" the control reference (i.e., CDM) to the single cue. Alternatively, the dual cue flight director presents the command steering for the two axes separately.

REQUIREMENT GUIDANCE (4.2.3.1)

Simulation trials comparing the two formats have consistently indicated that pilots perform the ILS approach with a higher degree of accuracy when using the dual cue flight director. In addition, the single cue flight director has one significant disadvantage in terms of failure indication. If by chance one of the axes of the ILS transmitter were to fail, the dual cue flight director indicates this failure by no longer presenting the steering bar representing that axis. The single cue director does not possess this capability. Typically, the axis which is failed is zeroed and the cue is altered in some fashion. In the case of the F–16 tadpole, the tail is removed and the circle is zeroed on the FPM. If the pilot fails to recognize the removal of the tail, he/she may believe proper control inputs are being made.

Based on human performance research, one would expect pilots to perform better with an integrated command reference. However, this prediction presupposes that pilots are integrating their control response so that they react to command changes in both axes simultaneously. Since performance seems to be better with a dual cue, we might assume that pilots are not integrating their control response and that they instead respond to each control axis individually, resolving one axis before resolving the other. Therefore we conclude that being able to separate the two command axes is of some benefit.

One advantage of the single cue over the dual cue is the reduced clutter achieved with the single cue flight director. Pilots have repeatedly commented that the size required to effectively implement a dual cue flight director causes a minor clutter problem in the center of the HUD FOV. The challenge then is to combine the best features of both the single and dual cues.

During symbology testing for the F–22, a compromise was achieved. A single cue reference which provides the axis separation of the dual cue was developed. This compromise was as simple as a symmetric cross consisting of a vertical and horizontal lines measuring 40 mr. The cross is positioned such that its intersection point corresponds with the intersection point of the dual axis flight director (Figure 30). Using this symbology, pilot performance was comparable to that achieved with the dual cue reference. Additionally, presentation of a single axis failure of the flight director is as simple as removing one of the cue's axis lines.

REQUIREMENT LESSONS LEARNED (4.2.3.1)

4.2.3.4 Bearing (VOR/waypoint) indicator. The bearing indicator (*Figure 31*) shall display the relative bearing to the selected navaid station and the radial from the station. The indicator shall consist of a bearing pointer, reference wings, and a readout. The pointer shall move about the center of the indicator to show the relative, magnetic bearing to the navaid station. The readout shall display the magnetic radial from the station. The pointer shall be removed and the readout shall display "XXX" whenever the navaid receiver is not receiving a signal.

The indicator shall be displayed in TACAN and ILS modes and shall be located in the upper right corner of the IFOV.

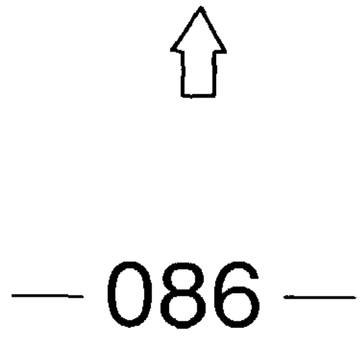


FIGURE 31. Bearing indicator.

4.2.3.4.1 Bearing pointer. The bearing pointer (*Figure 32*) displays the relative bearing to the selected navaid station. The pointer shall be located 20 mr from the center of the bearing indicator and shall be free to rotate a full 360 degrees about the center. If the navaid receiver is not receiving a signal from a station, then the pointer shall not display.

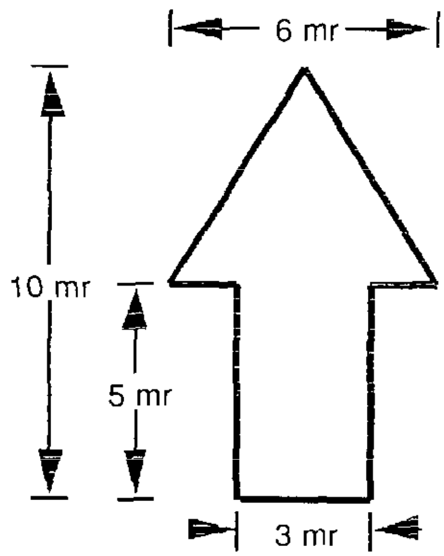


FIGURE 32. Bearing pointer.

4.2.3.4.2 Reference wings. The bearing pointer reference wings (*Figure 33*) display a reference point against which the bearing pointer can be read. The wings shall consist of two 8-mr horizontal bars that represent the aircraft's wings. The bars shall be located 10 mr from the center of the indicator.

FIGURE 33. Reference tics.

4.2.3.4.3 Radial readout. The radial readout shall display magnetic radial from the selected navaid to the nearest degree. The readout shall consist of a 3-digit number, full size, with the leading zero shown. The readout shall display XXX whenever the navaid is not receiving a signal. The readout shall be located at the center of the bearing indicator.

086 or XXX

4.2.4 Mission symbology

4.2.4.1 Acquisition cursor, air-to-air (A/A). This vertical situation display (VSD) symbol shall be displayed in all search modes to enable manual target designation. The dimensions of the A/A cursor shall be scaled to the target symbol size. (*Figure 34*)

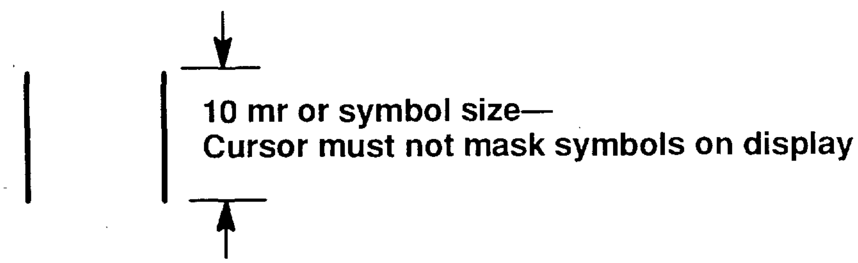


FIGURE 34. Acquisition cursor A/A.

REQUIREMENT RATIONALE (4.2.4.1)

This requirement provides the contractor with the symbol that has evolved from previous aircraft as a standard A/A acquisition cursor. This symbol is also used in the Joint Tactical Information Distribution System (JTIDS) tactical situation display as a designation and interrogation symbol.

REQUIREMENT GUIDANCE (4.2.4.1)

This symbol should be used on head-down displays (for example, radar) as a cursor to change ranges, interrogate targets, make assignments, and break assignments.

REQUIREMENT LESSONS LEARNED (4.2.4.1)

4.2.4.2 Acquisition cursor, air-to-ground (A/G) B-scope. This head down symbol shall be displayed with a B-scope presentation to indicate initial point (IP) or target location in range and azimuth (*Figure 35*).

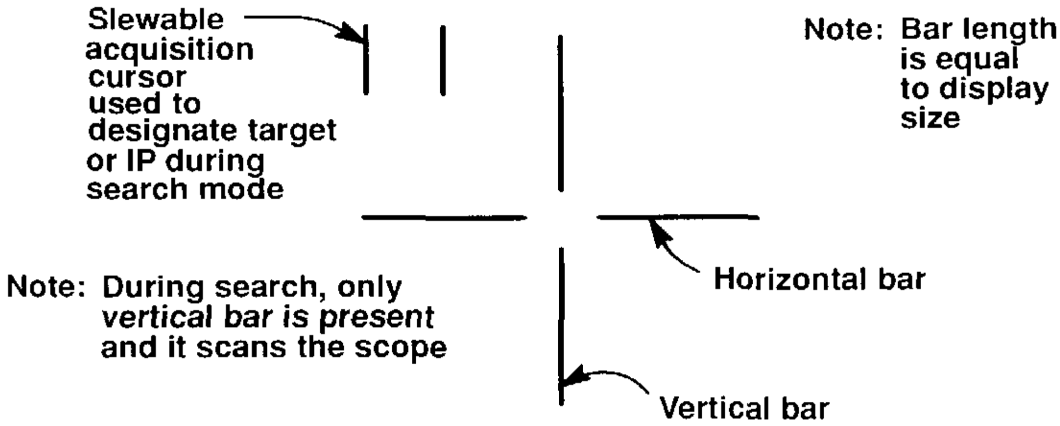


FIGURE 35. Acquisition cursor, A/G B-scope.

REQUIREMENT RATIONALE (4.2.4.2)

The horizontal part of this symbol serves as a range reference while the vertical part is an azimuth reference to assist in target track.

REQUIREMENT GUIDANCE (4.2.4.2)

This symbol should be used for B-scope displays.

REQUIREMENT LESSONS LEARNED (4.2.4.2)

4.2.4.3 Acquisition cursor, A/G PPI-scope. This head down symbol shall be displayed with a plan position indicator (PPI) scope presentation to indicate IP or target location in range and azimuth (*Figure 36*).

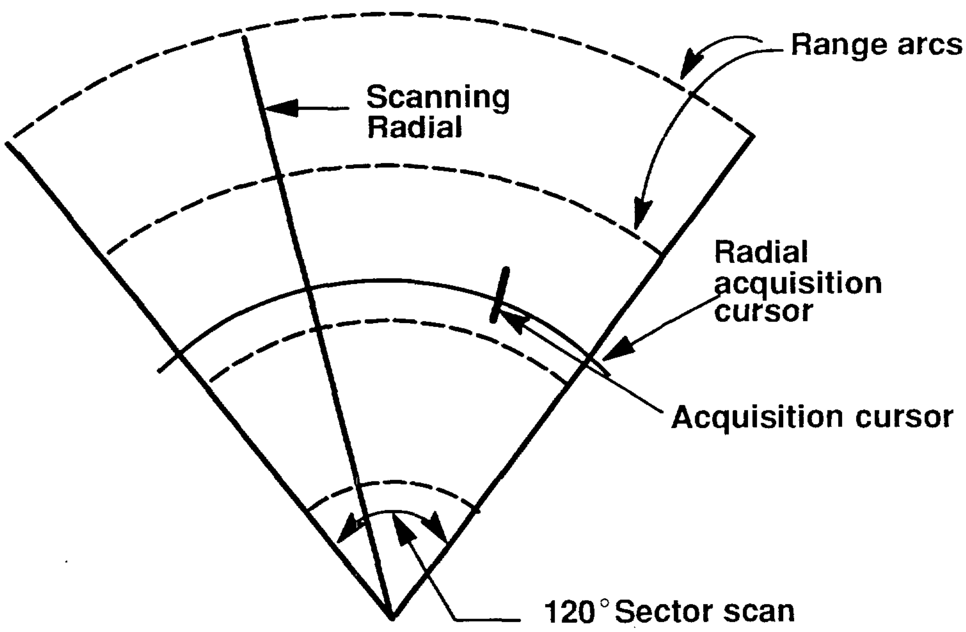


FIGURE 36. Acquisition cursor, A/G PPI-scope.

REQUIREMENT RATIONALE (4.2.4.3)

The arc portion of this symbol is centered on zero range so that all returns on the arc are at equal range from the airplane. The vertical part of this symbol serves as an azimuth reference.

REQUIREMENT GUIDANCE (4.2.4.3)

This symbol should be used for PPI-scope displays.

REQUIREMENT LESSONS LEARNED (4.2.4.3)

4.2.4.4 Aiming reticle, stadiametric. This symbol shall be used for stadiametric ranging. It shall be a variable diameter circle surrounding a _____-mr diameter circle and _____-mr diameter pipper dot (*Figure 37*).

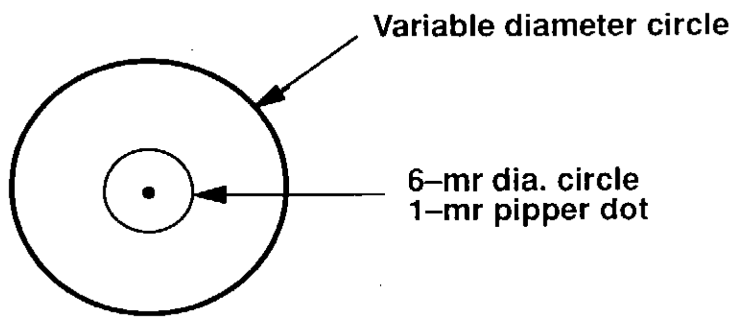


FIGURE 37. Aiming reticle, stadiametric.

REQUIREMENT RATIONALE (4.2.4.4)

This symbol provides the contractor with a standard stadiametric reticle for use on all applicable military aircraft. This symbol is used in A/A gunnery modes when radar range data is unavailable. The symbol is variable in size but manually set to one or more selectable ranges, for example, 700 feet or 1500 feet, in the case of the F–16. The target is at the selected range (target wingspan must be known) when the wings of the target just fill the inside of the outer, variable diameter circle (manually set via hands-on control).

REQUIREMENT GUIDANCE (4.2.4.4)

This symbol should be used for gunnery modes requiring the use of a stadiametric ranging reticle. The standard pipper size should be a 1-mr dot for minimum target obscuration, surrounded by a 6-mr circle to assist in symbol perception.

REQUIREMENT LESSONS LEARNED (4.2.4.4)

4.2.4.5 Aiming reticle, standby. This symbol shall be used for manual weapons delivery missions. It shall have ________ diameter and ________ diameter dashed octagons centered around a ________ pipper dot (*Figure 38*).

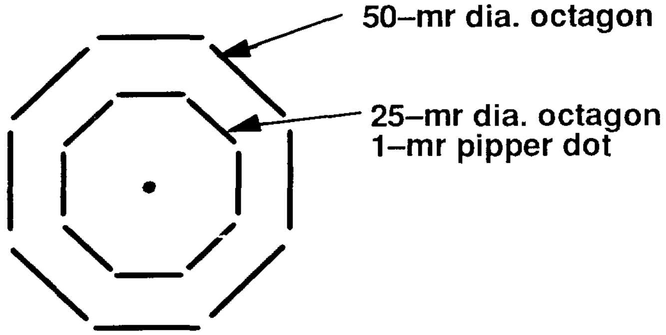


FIGURE 38. Aiming reticle, standby.

REQUIREMENT RATIONALE (4.2.4.5)

This symbol provides the contractor with a standard standby reticle for use on all military aircraft.

REQUIREMENT GUIDANCE (4.2.4.5)

This symbol should be used as a standby reticle for all manual aiming modes. Standby reticles should consist of at least a 25-mr and a 50-mr dashed octagon centered around a 1-mr pipper. Additional reference tics at 75-mr and 100 mr from the pipper are acceptable.

REQUIREMENT LESSONS LEARNED (4.2.4.5)

4.2.4.6 Allowable steering error (ASE) circle and steering dot for A/A attack. The ASE circle and the steering dot shall be used as A/A radar display features designed to provide either lead angle collision or pursuit steering, depending on the phase of an attack. The circle shall vary in size with respect to target range and target aspect angle (TAA) (*Figure 39*).

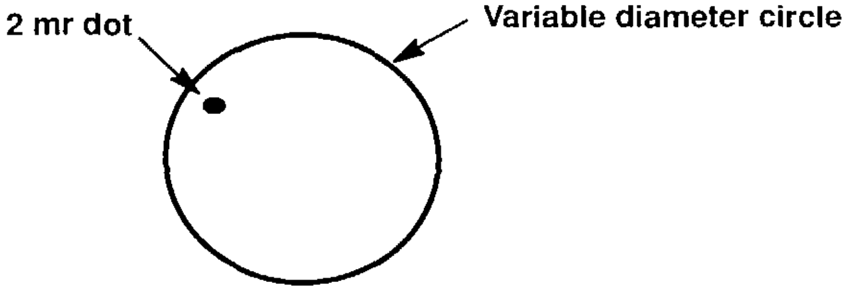


FIGURE 39. Allowable steering error (ASE) circle and steering dot (A/A attack).

REQUIREMENT RATIONALE (4.2.4.6)

This requirement provides the contractor with a standard ASE circle and steering dot for use in A/A aircraft. The ASE and dot were features of the F–4 radar display and the steering given with a centered dot varied depending on the phase of an attack. Outside missile R_{max}, a centered dot put the interceptor and target on a lead collision course. Inside R_{max}, it put the interceptor's missile and target on a lead collision course. Consequently, the steering law changed at R_{max}. In visual identification modes, a centered dot took the interceptor to a position relative to the target from which visual identification could be made (low 6 o'clock).

REQUIREMENT GUIDANCE (4.2.4.6)

This symbol should be mechanized to relate lead collision steering commands for missile attack.

REQUIREMENT LESSONS LEARNED (4.2.4.6)

4.2.4.7 Antenna azimuth and elevation markers. These carets shall indicate the current radar scan positions on a VSD. At lock-on, they shall indicate the azimuth and elevation angles of the target when read against scales (see *Figure 49*) on the edge of the display. Tick marks shall be every _______ degrees, and numerics, every _____ tick mark. (*Figure 40*)

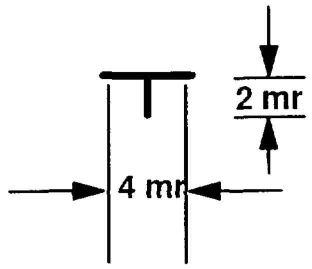


FIGURE 40. Antenna azimuth and elevation marker.

REQUIREMENT RATIONALE (4.2.4.7)

This symbol has evolved from previous aircraft.

REQUIREMENT GUIDANCE (4.2.4.7)

These markers should be used on head-down displays (that is, radar) as antenna markers. VSD antenna angle scales usually have tick marks every 10 degrees and numerics displayed every third tick mark or 30 degrees. The scales are normally located at the left and bottom edges of the display. See *Figure 49* for a scale representation. A similar indication of forward looking infrared (FLIR) pointing angles has been provided by small circles running along the top and side of the display.

REQUIREMENT LESSONS LEARNED (4.2.4.7)

4.2.4.8 Azimuth steering line (ASL). This symbol shall be displayed relative to the heading scale and shall provide a steering reference with respect to the FPM. The ASL shall be resolved vertically in the ground axes with respect to the ground stabilized reference point (for example, target or steerpoint) *(Figure 41)*.

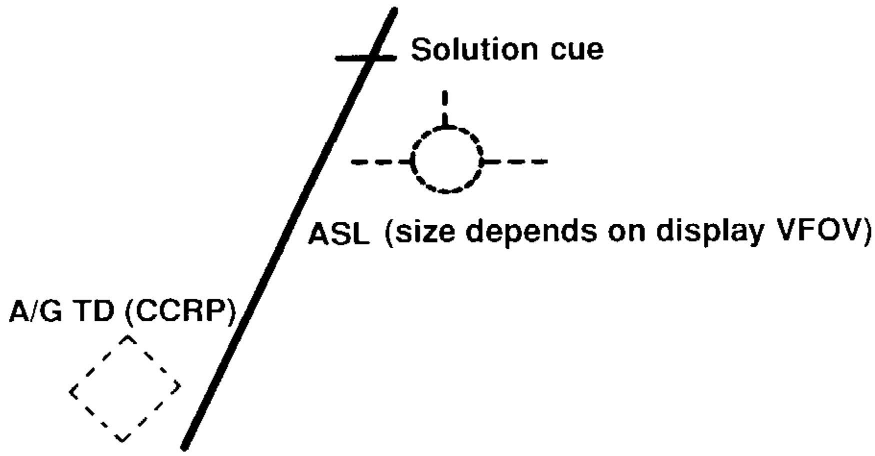


FIGURE 41. Azimuth steering line (ASL).

REQUIREMENT RATIONALE (4.2.4.8)

This symbol is used with the FPM in the continuously computed release point (CCRP) weapon mode to nullify azimuth steering error with respect to the designated target. The command heading pointer indicates the heading required to nullify any azimuth error with respect to the designated target.

REQUIREMENT GUIDANCE (4.2.4.8)

This symbol should be used for HUD CCRP modes. The gearing of the ASL need not be determined by the gearing of the heading scale. Gearing should be dictated by the aircraft's operational weapon delivery capabilities.

REQUIREMENT LESSONS LEARNED (4.2.4.8)

4.2.4.9 Beacon symbol (steerpoint symbol, destination symbol, initial point (IP) symbol). This symbol is displayed on the head-down and head-up displays. This symbol shall be used for navigation, fixtaking, weapon delivery, and tanker rendezvous to display the range and bearing of steerpoints or coded beacon replies from ground-based or airborne beacons (*Figure 42*).

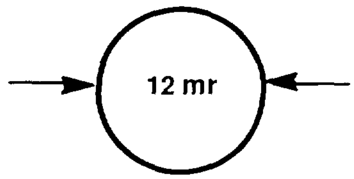


FIGURE 42. Beacon symbol (steerpoint symbol, destination symbol, initial point symbol).

REQUIREMENT RATIONALE (4.2.4.9)

This symbol represents either a beacon, steerpoint, destination, or IP symbol because each is a representation of range and bearing to a point of interest on the navigation route other than a target. It is also the recommended JTIDS symbol for navigation waypoints on head down displays. The JTIDS symbol is a dashed circle instead of solid. The difference, from a human factors viewpoint, is probably negligible. Dashed circles require less stroke time when stroke generated and occlude less when viewed through a HUD, but for a 12-mr circle, the differences are probably negligible.

REQUIREMENT GUIDANCE (4.2.4.9)

This symbol is suitable for use on head-up and head-down displays. Using a dashed circle for beacons, destinations and steerpoints and a solid circle for IPs is another alternative if display stroke writing time is not an issue. Careful consideration should be given to using this as a code for critical information because of the minor difference in appearance.

REQUIREMENT LESSONS LEARNED (4.2.4.9)

The F–16 uses two symbols for this function: one head down and one head up. From a human factors viewpoint, it is not a good practice to have two different symbols mean the same thing. At the time of the design of the head-up/head-down interface for the F–16, the requirement to use the same symbol on both displays was not specified by the government due to a lack of standard requirements.

4.2.4.10 Bombfall line (BFL). The bombfall line shall extend between the FPM and aiming pipper (impact point) and shall approximate the trajectory that the weapon assumes to the target (*Figure 43*).

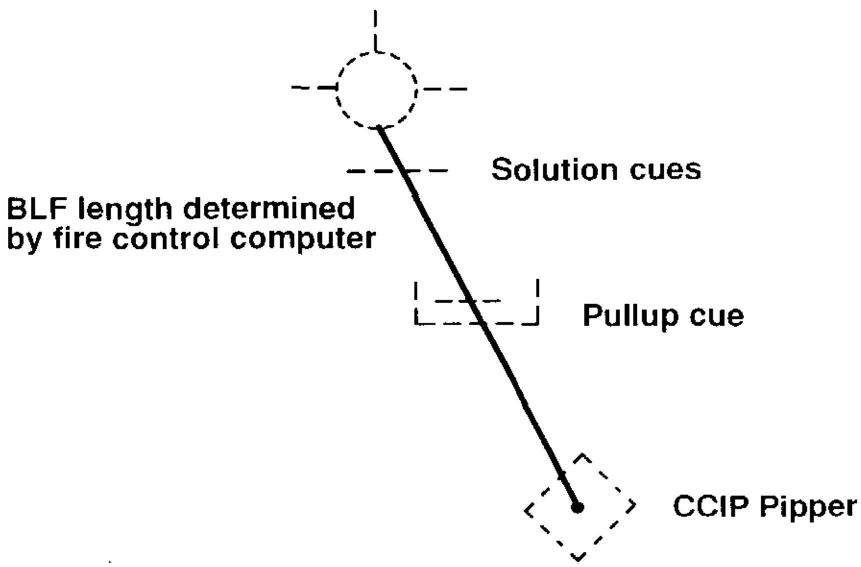


FIGURE 43. Bombfall line (BFL).

REQUIREMENT RATIONALE (4.2.4.10)

This symbol is used with the FPM to display weapon trajectory from the aircraft to the ground-based target. There are several possible mechanizations for a BFL on a HUD. Improved mechanizations evolve from advances in electronic technology that improve HUD symbology processing. There is no recommended standard BFL symbol because it may prove inferior to later designs.

REQUIREMENT GUIDANCE (4.2.4.10)

This symbol should be used for HUD continuously computed impact point (CCIP) modes with the A/G CCIP target designator (TD). The BFL symbology should be implemented to provide for flexible weapons release attitudes.

REQUIREMENT LESSONS LEARNED (4.2.4.10)

4.2.4.11 **Breakaway symbol.** This symbol shall be displayed at minimum weapon release range and/or upon reaching the minimum safe pull-out altitude during A/G weapon delivery. This symbol shall flash at 5 Hz when necessary to indicate a need for immediate pull-up of the aircraft (*Figure 44*).

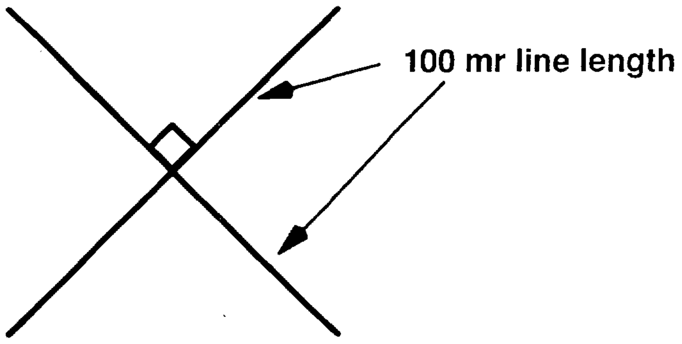


FIGURE 44. Breakaway symbol.

REQUIREMENT RATIONALE (4.2.4.11)

This symbol indicates a need for immediate pull-up of the aircraft. This symbol has evolved from previous aircraft as the standard breakaway symbol as well as the NATO standard.

REQUIREMENT GUIDANCE (4.2.4.11)

This symbol should be used on head-down and head-up displays for breakaway.

REQUIREMENT LESSONS LEARNED (4.2.4.11)

This symbol should always be used to indicate that ground clobber is imminent and requires immediate pilot action. The symbol should have a very clear meaning dictating one set of pilot actions. It should never be able to be deselected at the pilot's option.

4.2.4.12 Continuously computed impact line (CCIL). This symbol shall be used to display a range of simulated bullet points associated with flight conditions during snapshoot gunnery solutions. Bullet time-of-flight (TOF) points shall be marked by tick intervals on the CCIL at _____, _____ and _____ seconds TOF (*Figure 45*).

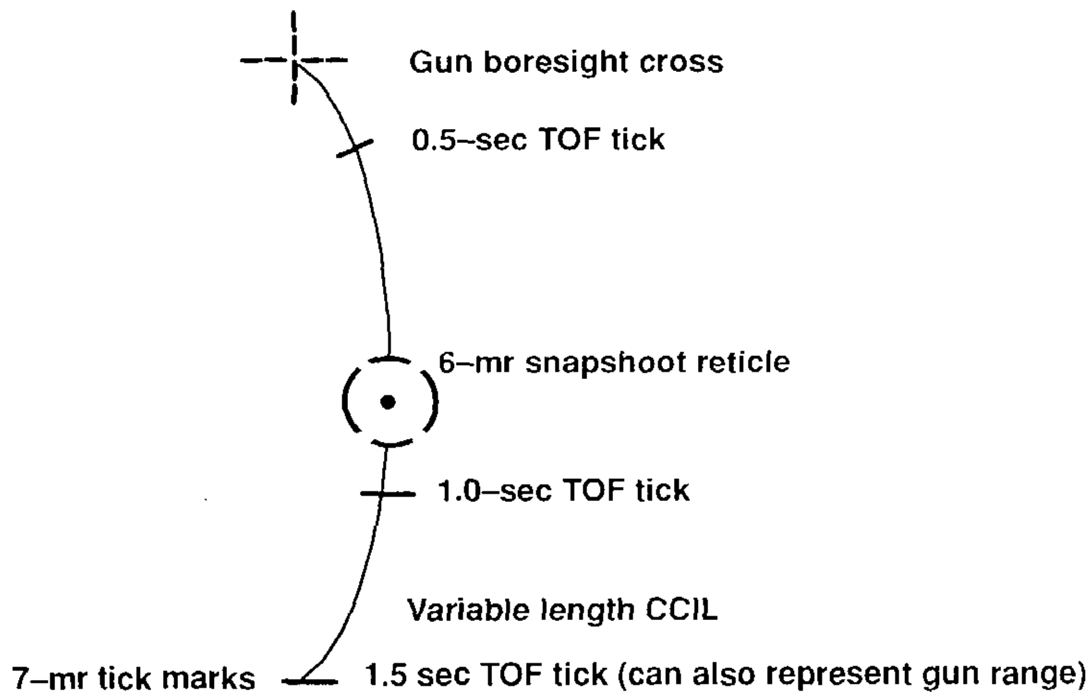


FIGURE 45. Continuously computed impact line (CCIL).

REQUIREMENT RATIONALE (4.2.4.12)

This requirement provides the contractor with a standard CCIL symbol that is used on the HUD in air combat snapshoot gunnery modes.

REQUIREMENT GUIDANCE (4.2.4.12)

This symbol should display at least three bullet points, marked by tick intervals on the simulated bullet line of flight, usually at 0.5, 1.0, and 15.0 seconds bullet time-of-flight (TOF). Tick position may also be used to reflect *stadiametric range, which is a more useful cue for the pilot to visually estimate target range.*

REQUIREMENT LESSONS LEARNED (4.2.4.12)

4.2.4.13 Gun cross. This symbol shall be used for gun target tracking on HUDs to indicate the projectile conversion point (with no corrections) on the aircraft boresight axis or the projectile position at some distance corresponding to a normal firing range (for A/G dedicated aircraft). A reticle similar to this cross is used in forward looking infrared (FLIR) and radar presentations to represent field of view (FOV) center or a cursor (*Figure 46*).

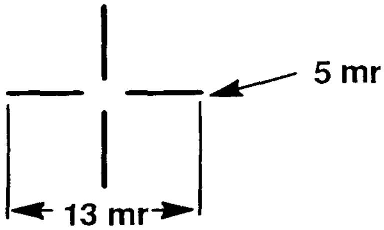


FIGURE 46. Gun cross.

REQUIREMENT RATIONALE (4.2.4.13)

A cross symbol is often associated with a location or target. It can also be used as an aiming reticle for electro-optical and laser-guided weapons. A 2-mr pipper located at the center of the cross would occlude a 2-foot circle every 1000 feet of slant range, and should not be used.

REQUIREMENT GUIDANCE (4.2.4.13)

The recommended gun cross to use would be an open cross (no pipper) to facilitate target acquisition.

REQUIREMENT LESSONS LEARNED (4.2.4.13)

This symbol has been used as the pitch reference symbol in the F–16 HUD.

4.2.4.14 Lead computing optical sight (LCOS) track line. This line shall provide an azimuth tracking reference joining the gun boresight cross with the A/A aiming reticle. The LCOS lag line symbol shall indicate the degree of pipper unsettlement (lag), if any, and the direction the pipper is moving for a settled solution (*Figure 47*).

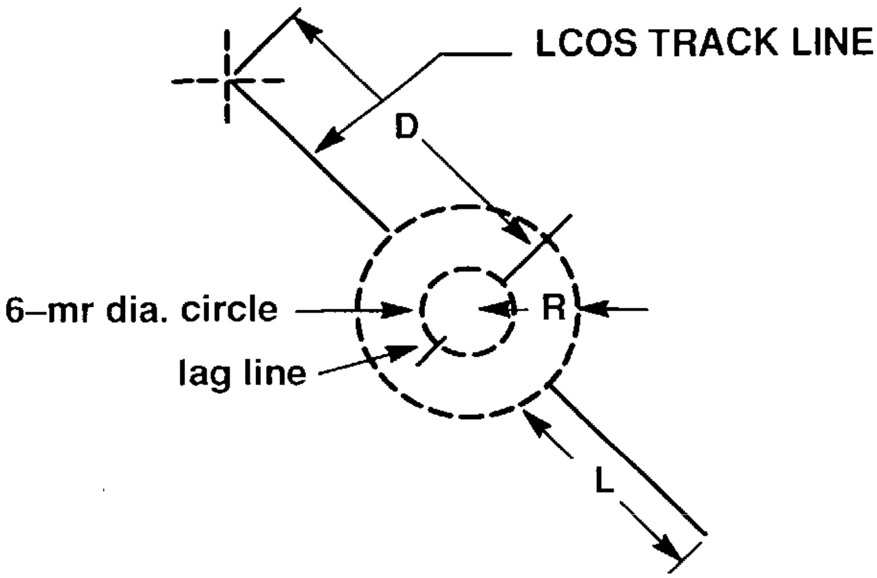


FIGURE 47. Lead computing optical sight (LCOS) track line and lag line.

REQUIREMENT RATIONALE (4.2.4.14)

This symbol facilitates gunnery solutions by providing a tracking reference and pipper lag indication.

REQUIREMENT GUIDANCE (4.2.4.14)

The length of the LCOS track line below the aiming reticle varies in proportion to the distance of the track line between its gun cross origin and the aim reticle center, and the aim reticle radius as defined here: (1) D represents the track line distance between the gun cross origin and the aim reticle center; (2) R represents the aim reticle radius; and (3) L represents the line segment length below the aim reticle.

If D	>	2R	then L = R
If R	<	D > 2R	then L = D – R
If D	<	R	then L = zero

The magnitude of the LCOS lag line indicates the degree and direction of pipper unsettlement (lag). When the solution settles out, the lag line disappears.

REQUIREMENT LESSONS LEARNED (4.2.4.14)

It is understood that the LCOS lag line is of little use in practice and is frequently ignored.

4.2.4.15 Pull-up anticipation cue. The symbol shall indicate an approaching pull-up requirement in A/G modes. The roll stabilized symbol shall be caged in azimuth and referenced to the FPM (*Figure 48*).

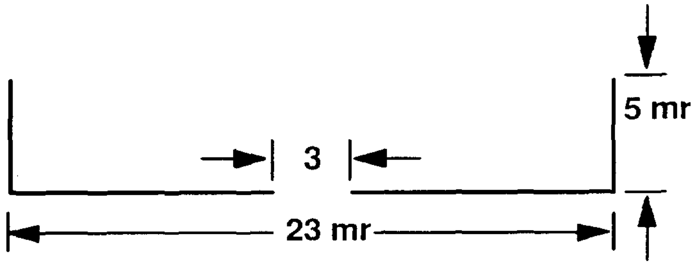


FIGURE 48. Pull-up anticipation cue.

REQUIREMENT RATIONALE (4.2.4.15)

The U-shaped symbol is associated with the up direction by virtue of its shape, making it a suitable choice for this function.

REQUIREMENT GUIDANCE (4.2.4.15)

A good rationale for the pull-up cue is that when the pull-up cue moves up and becomes coincident with the flight path marker (velocity vector), a 4.0 G pull-up should be achieved within 2.0 seconds and maintained to clear the ground by a margin of 1000 feet. However, the ground clearance height should be a function of dive angle. For example, in a 5-degree dive, a 100-foot ground clearance could be acceptable for strafing attacks whereas 1000 feet might be a minimum for a 60-degree dive. Furthermore, it may be weapon type- and number-dependent; for example, a 1000-pound free-fall bomb produces an increasing risk of fragmentation damage to the delivering aircraft if it goes below 1500 feet. On the other hand, similar but retarded weapons can be delivered safely at 200 feet.

REQUIREMENT LESSONS LEARNED (4.2.4.15)

4.2.4.16 Radar range scale. This fixed scale shall be displayed after lock-on occurs. The moving caret shall indicate target range. See *4.3.1* for a description of R_{max} 1, R_{max} 2, and R_{min} (*Figure 49*).

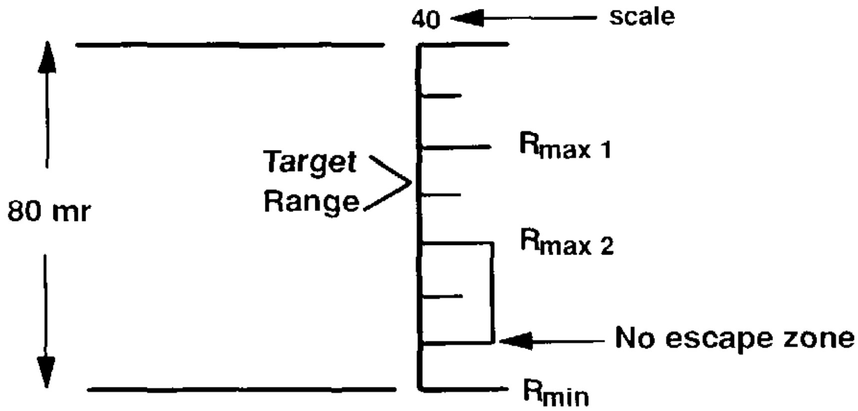


FIGURE 49. Radar range scale.

REQUIREMENT RATIONALE (4.2.4.16)

This scale provides range, range rate, and launch zone cues for A/A missile modes in an easily interpreted format.

REQUIREMENT GUIDANCE (4.2.4.16)

This linear scale is the alternate symbol to be used if the circular analog range bar is not used. It is suggested that the radar range scale move with the target to preclude the pilot having to shift attention between the target and the range scale during the engagement. Also, the basic structure of the range scale should be retained on the display after the first radar lock is accomplished. Then, if the radar continuously breaks lock, this prevents the blanking and reappearance of a large amount of symbology. The large dynamic range of the scale could be combined with adequate resolution by implementing a range of scales, the maximum reading of which could be indicated by sets of numerics displayed in conjunction with the scale.

REQUIREMENT LESSONS LEARNED (4.2.4.16)

4.2.4.17 Solution cues, air-to-ground (A/G). These symbols shall indicate when a computed level release or toss release solution is available for the weapon selected. They shall vary in position along the bombfall line with reference to the FPM. The first optimum weapon release cue shall represent the first or lower solution to the equation for the selected weapon. As a solution is approached, the cue shall move down the BFL. The second optimum weapon release cue shall represent the last or upper solution to the equation for the selected weapon and shall move in the same manner as the first *(Figure 50)*.

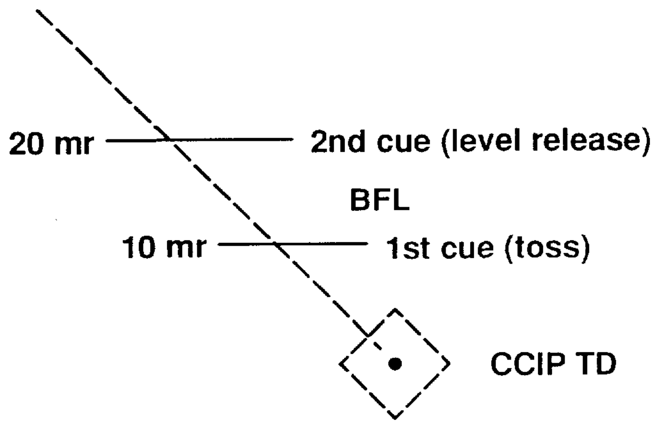


FIGURE 50. Solution cues (A/G).

REQUIREMENT RATIONALE (4.2.4.17)

These symbols serve as in-range and release anticipation indicators. As the release point is approached, the cues move down the bombfall line. When either cue intersects the FPM, the weapon could be released, depending on the solution chosen for release.

REQUIREMENT GUIDANCE (4.2.4.17)

These symbols should be used for A/G weapon delivery solution cues.

REQUIREMENT LESSONS LEARNED (4.2.4.17)

4.2.4.18 Target designator (TD)/radar lock-on, air-to-air. This symbol shall be displayed when the radar is angle tracking a target to indicate the antenna line of sight to the target (*Figure 51*).

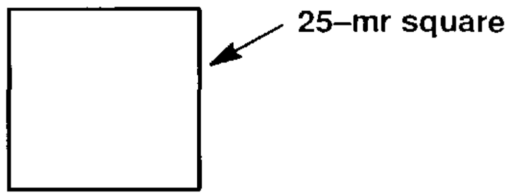


FIGURE 51. Target designator/radar lock-on.

REQUIREMENT RATIONALE (4.2.4.18)

This symbol enables the pilot to locate and track an air-to-air target.

REQUIREMENT GUIDANCE (4.2.4.18)

This symbol should be provided after radar lock-on. When the target is outside the total FOV, the symbol should be deleted and replaced by a target locator line which extends from the HUD boresight position toward the target's location, indicating radar antenna look angle.

REQUIREMENT LESSONS LEARNED (4.2.4.18)

4.2.4.19 Target designator, A/G continuously computed impact point (CCIP). This HUD symbol shall be attached to the BFL and shall represent the weapon impact point if the weapon is released at that point in time. CCIP placement shall be based on computer computations (*Figure 52*).

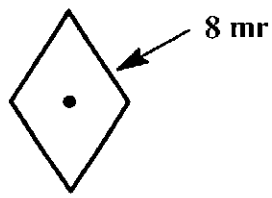


FIGURE 52. A/G CCIP TD.

REQUIREMENT RATIONALE (4.2.4.19)

This HUD symbol is provided to show azimuth and elevation of the computed weapon impact point. It is attached to the BFL and is flown to the designated target. A diamond is the recommended standard for a designated target.

REQUIREMENT GUIDANCE (4.2.4.19)

This symbol should be used for HUD displays in aircraft with a CCIP weapon delivery mode.

REQUIREMENT LESSONS LEARNED (4.2.4.19)

4.2.4.20 Target designator, A/G continuously computed release point (CCRP). This HUD symbol shall display azimuth and elevation of a ground target or weapon impact point. It shall be slewable to permit corrections (*Figure 53*).

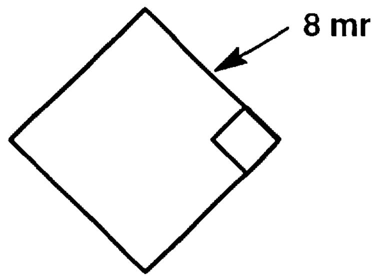


FIGURE 53. A/G CCRP TD.

REQUIREMENT RATIONALE (4.2.4.20)

This HUD symbol is provided to enable the pilot to locate and track an A/G target. A diamond is the recommended standard for showing azimuth and elevation of a designated target. This symbol is used with the azimuth steering line (ASL) and FPM to null steering error to the designated target.

REQUIREMENT GUIDANCE (4.2.4.20)

This symbol should be used for HUD displays in aircraft with a CCRP weapon delivery mode. When the target is outside the HUD total field-of-view, the symbol should be deleted and replaced by a target locator line which extends from the HUD boresight position toward the target's location, indicating direction of radar antenna look angle in radar modes or direction to the target's inertial navigation coordinates when radar isn't used.

REQUIREMENT LESSONS LEARNED (4.2.4.20)

4.2.4.21 **Target locator line (A/A and A/G).** This symbol shall indicate location of target inertial navigation coordinates or radar antenna look angle when target lock-on occurs at angles outside of the *HUD total field of view* (TFOV) (*Figure 54*).

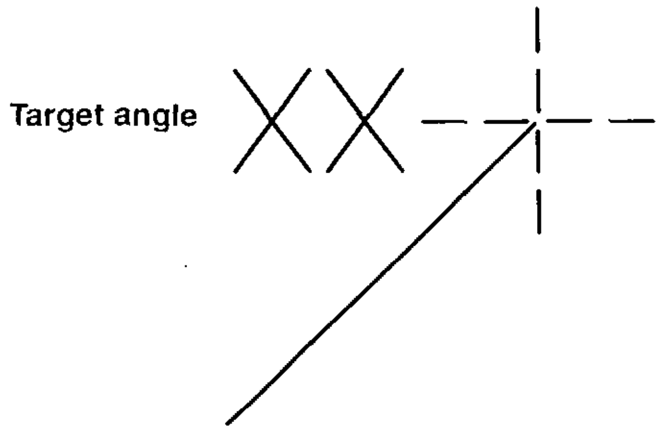


FIGURE 54. Target locator line.

REQUIREMENT RATIONALE (4.2.4.21)

This line is used in place of the steerpoint or target symbol when the point of interest is outside the HUD TFOV. The line is drawn from the gun cross to the bearing location of the target.

REQUIREMENT GUIDANCE (4.2.4.21)

This symbol should be positionable 360 degrees about the gun boresight symbol. Target angle should be presented numerically in degrees.

REQUIREMENT LESSONS LEARNED (4.2.4.21)

This symbol has received much consideration and was incorporated in this standard because of pilot acceptability. Pilots have stated that the characteristics of the locator line facilitate pilot assessment of target range and bearing location. It is realized that an out-of-FOV target should be represented consistently across all displays, that is, by flashing the limited symbol as recommended in *4.2.4.18*. However, pilots feel a line extending from the HUD gun cross to the target location does not contribute that much to clutter and it does enhance situational awareness.

4.2.4.22 Target identification set, laser (TISL) reticle. This symbol shall be displayed superimposed on the target when the TISL system is tracking a target. The TISL direction line shall be a dashed line connecting the TISL reticle to the aiming pipper to facilitate target azimuth alignment and tracking (*Figure 55*).

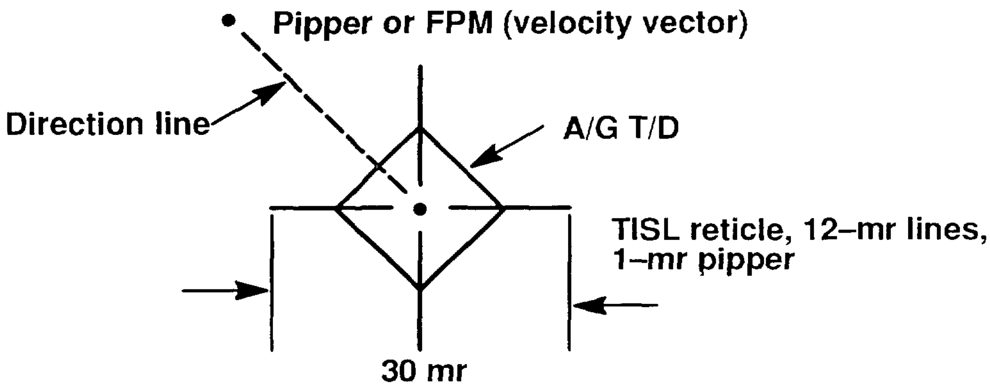


FIGURE 55. Target identification set, laser (TISL) reticle and direction line.

REQUIREMENT RATIONALE (4.2.4.22)

This symbol is provided when the TISL system is identified and is tracking a laser illuminated target. The direction line aids in azimuth alignment and tracking of the target when the target is out of the central FOV.

REQUIREMENT GUIDANCE (4.2.4.22)

The symbol is displayed in TISL modes to indicate azimuth and elevation of ground target location.

REQUIREMENT LESSONS LEARNED (4.2.4.22)

4.2.4.23 Terrain following (TF) cue. This symbol shall provide vertical TF steering cues. It shall be displayed relative to the FPM and is normally caged to the FPM azimuth (*Figure 56*).

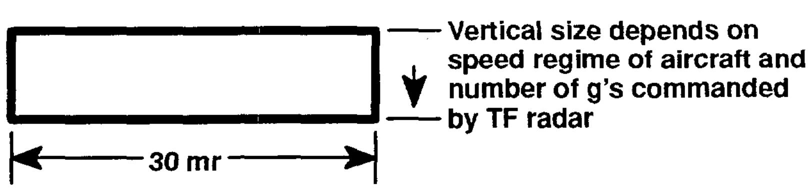


FIGURE 56. Terrain following cue.

4.3 Symbols and layouts. The symbols defined in section *4.3* shall be drawn using the symbols shown in figures accompanying each paragraph as guidance.

REQUIREMENT RATIONALE (4.3)

The symbols and formats in section *4.3* should be used as baselines when evaluating the symbols proposed by a contractor for these functions. The information required to be displayed depends on the weapon system capability and mission requirements. For example, the AMRAAM system is capable of displaying multiple target information head up and head down.

REQUIREMENT GUIDANCE (4.3)

The criteria used for acceptance of the proposed symbols should be based on human factors design criteria for information coding and information presentation. Several information sources are available which provide excellent discussions in this area. (See *Janair Report No. 680505, AFFDL–TR–70–174, Human Engineering Guide to Equipment Design*, and *ASD–TR–81–5014.*) At least the following requirements should be used to evaluate new symbology:

a. Each symbol shall be unique by virtue of at least two coding characteristics. Each target type should not only be unique in shape, but also should maintain its same shape throughout the attack sequence. Information about the target (TAA, closure rate, in/out of weapon envelope, priority, and the like) should be provided through additional symbology, not via a change in target shape. The use of either a raster, calligraphic, or x–y matrix display shall not adversely affect these coding characteristics.

b. The meaning and motion of displays shall be consistent throughout all modes of the display and between displays. Scaling and gain changes are permitted between modes and displays. One exception to this is symbols that are filled in on head-down displays and are also displayed on the HUD. They cannot be filled in on the HUD due to scene obscuration and must be carefully recoded for use on the HUD. This is one reason for using different shapes for target types instead of using the same shape with different target types being determined by an empty symbol, a partially filled-in symbol, and totally filled-in symbol. Such coding should be reserved for less critical information or for supplementing another code.

c. The sense of aircraft control symbol motion should be compatible with the motions of the corresponding controller.

d. New symbols being proposed should be reviewed from a DOD perspective, where possible, to prevent conflict with Navy, Army, and International symbcl standards. The designer should be familiar with the symbology used in all Air Force aircraft (e.g., A–7, A–10, F–15, and F–16) and the Navy F–18 since this standard does not include all the symbology which is currently in use. Since most Air Force aircraft use only a part of the recommended standards, compromises may be necessary to maintain commonality within an existing aircraft program.

REQUIREMENT LESSONS LEARNED (4.3)

5.3 Symbols and layouts verification. All display symbology in section *4.3* shall be verified by visual inspection of the shape and dimensions of each symbol and alphanumeric character and a functional verification (hot bench test or flight test) of the operational characteristics of each symbol. New symbols proposed in lieu of those in section *4.3* must provide a justifiable improvement in system capability and must be functionally verified.

VERIFICATION RATIONALE (5.3)

Visual inspection is adequate to verify shape and dimensions of each symbol and alphanumeric character. Hot bench or flight tests are adequate to verify the operational characteristics of each symbol.

VERIFICATION GUIDANCE (5.3)

Verification of the symbols chosen should be performed during human factors test and evaluation of the full-scale development effort. Progress, however, should be monitored from the initial design to final development to ensure continued compliance with the requirements. Symbol geometry, font, format, dimensions, and mechanizations are normally defined in the Critical Item Development Specification for each of the displays being used.

The requirements and verifications for acceptance of dynamic relationships between symbols, displays, and aircraft systems are beyond the scope of this document. Display resolution, brightness, uniformity, contrast, flicker, noise, minimum line movement, etc., are display characteristics which are specified in *AFGS–87213*. *MIL–STD–1776* deals with flight instrument displays, control panel layout and color lights. *MIL–STD–1472* contains a section on human factors display requirements.

VERIFICATION LESSONS LEARNED (5.3)

4.3.1 Aiming reticle, air to air. *This symbol shall be displayed during air-to-air* (A/A) combat modes to aid in visual target acquisition. Subparagraphs *4.3.1.a* through *4.3.1.k* contain the standard symbols which shall be used with the reticle to display target and weapon parameters to the pilot. (*Figures 57a* through *57k*.)

a. Analog closure rate caret. This symbol shall be displayed around the inside perimeter of the aiming reticle. It shall be scaled to _____ per clock position with positive and negative rates limited at 5 o'clock (______) and 7 o'clock (_______), respectively (*Figure 57a*).

b. Circular analog target range bar. This symbol shall display range to target and shall be scaled to _____ or _____ per clock position (*Figure 57b*).

c. Range indices. Tick marks shall be used on the reticle to denote a clock position (*Figure 57c*).

d. In-range markers. These symbols shall be used to display minimum and maximum target ranges suitable for the weapon selected (*Figure 57d*).

e. R_{max} 1 reference tick. The R_{max} 1 symbol shall denote the maximum launch range computed from the aerodynamic range of the weapon selected against a nonmaneuvering target (*Figure 57e*).

f. R_{max} 2 *reference tick. The* R_{max} 2 *range symbol shall be computed for a target evasive maneuver at the terminal phase of missile flight* (*Figure 57f*).

g. R_{min} reference tick. The R_{min} range symbol shall be computed from the minimum time of flight required for missile guidance and arming (*Figure 57g*).

h. Pipper, A/A. This _____ diameter dot shall be used in all A/A modes except missile, where it is usually replaced by a missile seeker head circle or diamond at missile boresight. Pipper position depends on radar computations of target aircraft range (*Figure 57h*).

i. Range at bullet one second TOF. This tick mark shall denote bullet range at one second TOF or *maximum gun range* (*Figure 57i*).

j. Snapshoot reticle. The A/A snapshoot reticle shall be depicted as a ______ diameter circle. The reticle is positioned on the CCIL at target range (*Figure 57j*).

k. Target aspect angle (TAA). TAA shall depict the target velocity vector direction such that 12 o'clock denotes 180–degree difference between aircraft and target velocity vector, 6 o'clock denotes zero difference and 9 o'clock denotes the target is passing left *to right in front of aircraft nose* (*Figure 57k*).

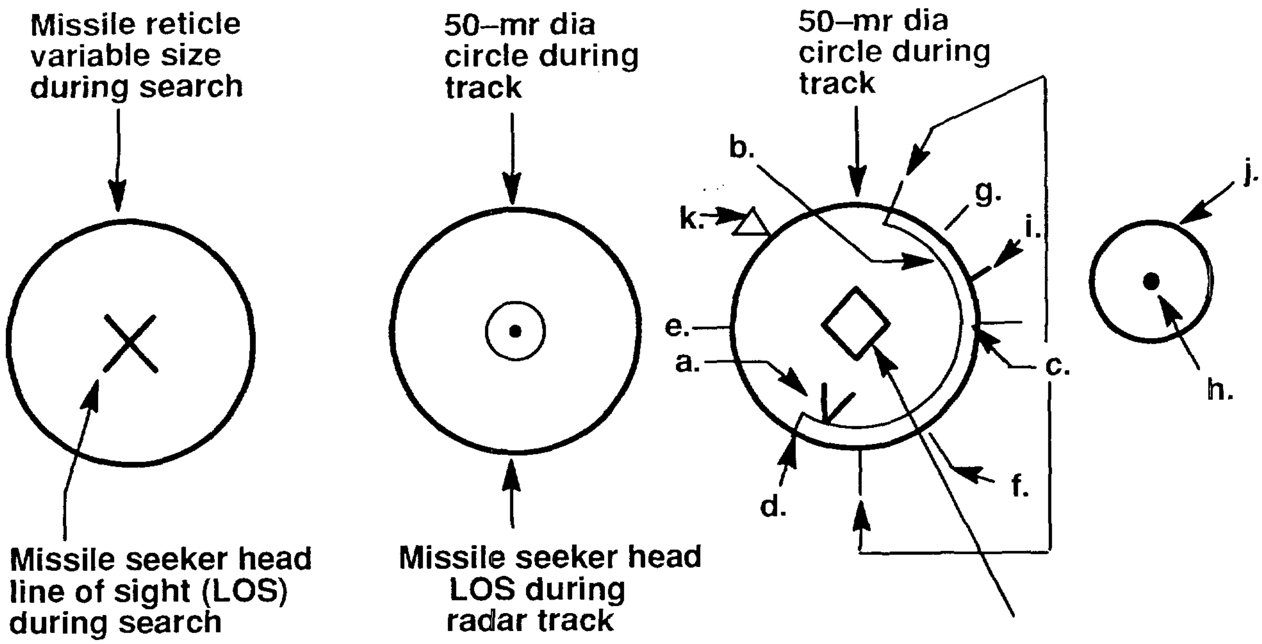


FIGURE 57. Aiming reticle, air-to-air (A/A).

REQUIREMENT RATIONALE (4.3.1)

This set of symbols provides the contractor with a standard A/A reticle ensemble to be used in all procuring activity aircraft. This approach minimizes confusion and reduces symbol proliferation.

REQUIREMENT GUIDANCE (4.3.1)

This symbol should be used as a baseline reticle for all A/A aiming modes. The analog closure rate caret is normally scaled to +/–100 knots per clock position and limited to +/–500 knots. The circular analog target range bar is normally scaled to 1000 or 3000 feet per clock position. The pipper is usually one milliradian in diameter. The A/A snapshoot reticle is 6 mr in diameter.

REQUIREMENT LESSONS LEARNED (4.3.1)

4.3.2 Aiming reticle, air-to-ground (A/G). This _____-mr diamond reticle shall be displayed during air-to-ground weapon delivery modes to enable target acquisition. It shall be centered on the pipper. Subparagraphs *4.3.2.a* through *4.3.2.c* contain the standard symbols which shall be used with the reticle to display target and weapon parameters to the pilot (*Figure 58*).

a. Target in-range bar. The range bar shall display when the target is in range for the weapon selected (*Figure 58a*).

b. Pipper, A/G. This ______ diameter dot shall be used in all A/G modes (*Figure 58b*). Pipper position depends on A/G mode selected. It shall be positioned in azimuth to one of the following points, depending on the weapon delivery mode selected:

(1) To the flight path marker (FPM)

(2) To the weapon impact point (CCIP)

(3) To the HUD depression angle (manual setting)

(4) To the weapon boresight, e.g., electro-optical (EO) weapon

(5) To the IR weapon seeker head position.

c. Reticle eyebrows. The eyebrows are two short, vertical lines centered above the pipper at _____ and _____. They appear only when the reticle is depressed _____ or more (*Figure 58c*).

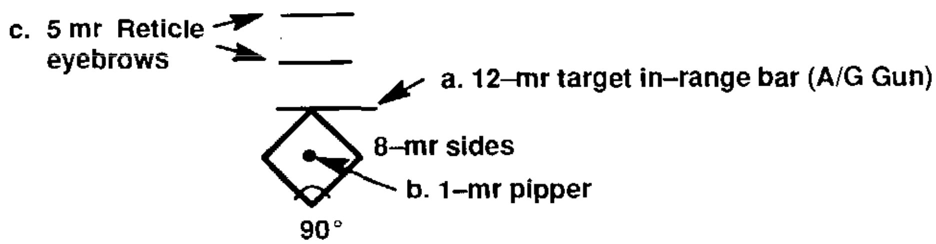


FIGURE 58. Aiming reticle, air-to-ground.

REQUIREMENT RATIONALE (4.3.2)

This set of symbols provides the contractor with a standard A/G reticle ensemble to be used in all Air Force aircraft. This approach minimizes confusion across aircraft display symbol sets while reducing symbol proliferation.

REQUIREMENT GUIDANCE (4.3.2)

This symbol should be used as baseline reticle for all A/G aiming modes. An A/G reticle should be an 8-mr diamond with a 1-mr pipper dot. Reticle eyebrows should be centered above the pipper at 25 mr and 50 mr when the reticle is depressed 100 mr or more (fixed depression sights). The eyebrows are unnecessary for computed solutions. For A/G gun, a target in-range cue (12 mr bar) may be used.

REQUIREMENT LESSONS LEARNED (4.3.2)

4.3.3 Character fonts. The following types of character fonts, as applicable, shall be used on weapon system displays requiring alphanumeric information. See *AFGS-87213* for the recommended character sizes for each type of font.

a. Dot matrix font. The font used for dot matrix displays shall comply with the following design criteria (*Figure 59a*):

(1) The font shall be as similar to the raster-generated font (*4.3.3.b*) as possible so that character style can be standardized across electronic displays in the cockpit.

(2) Horizontal and vertical segments or strokes making up each character shall be at least two pixels wide to reduce confusion of one character with another in the event of a single row or column failure.

(3) Character height shall conform with the criteria in *AFGS-87213.*

(4) Character stroke width shall conform with the criteria in *AFGS-87213* except that stroke width (SW) shall be greater than 0.12 h and less than 0.22 h, where h is character height.

An example of a dot matrix font for aircraft cockpit displays is shown in *Figure 59a.* The 7 x 9 matrix size shown is the minimum matrix size suitable for use in aircraft cockpit displays. If display size, resolution, and information density permit, larger matrix sizes with two pixel stroke widths are recommended.

Any proposed font shall be subject to procuring activity approval.

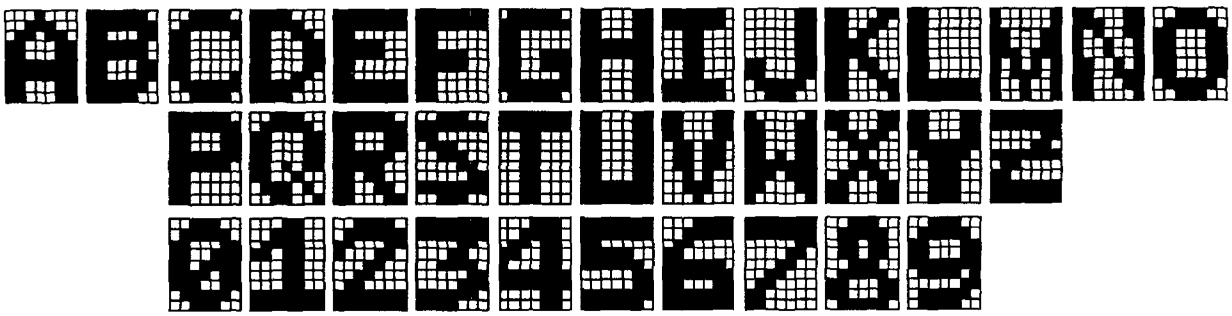


FIGURE 59. a. Dot matrix font.

b. Raster-generated font. The raster-generated character font shall be used for weapon system displays requiring raster-generated characters. An example of a raster–generated *font for aircraft cockpit* displays is shown in *Figure 59b.* Any proposed font shall be subject to procuring activity approval.

FIGURE 59. b. Raster-generated font.

c. Stroke-written font. Weapon system displays requiring stroke-written characters shall use the stroke–written font type. An example of a stroke–written font for aircraft cockpit displays is shown in *Figure 59c.* The size of font should be scaled in accordance with display resolution requirements. Where context clearly differentiates the zero from the alphabetic character "O," the slash through the zero is optional. Any proposed font shall be subject to procuring activity approval.

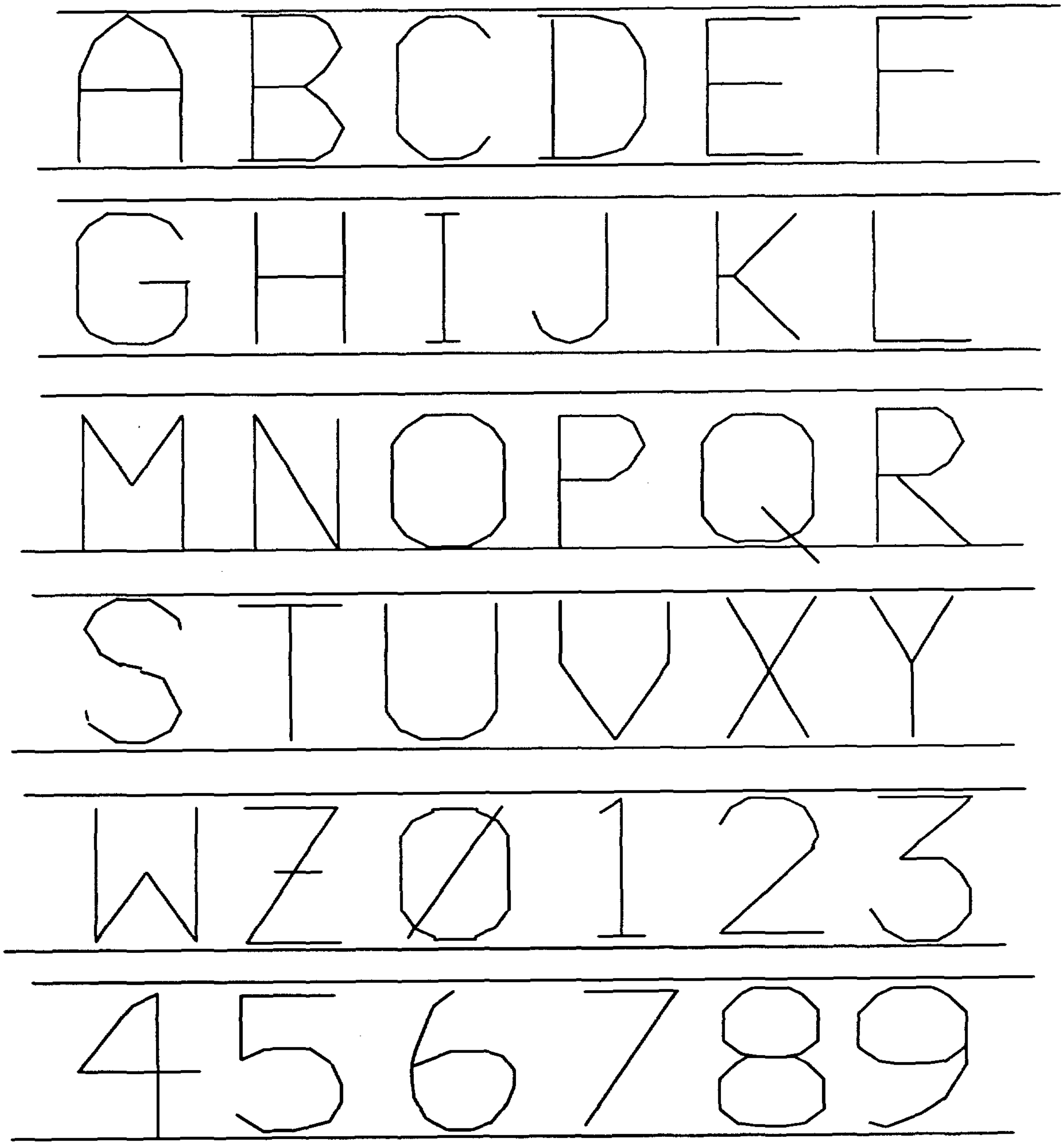


FIGURE 59. c. Stroke-written font.

REQUIREMENT RATIONALE (4.3.3)

The reason for establishing standard fonts is to ensure that displayed information can be read quickly and accurately. Research shows that character brightness, contrast, height/subtense angle, ratio of stroke width to height, spacing between characters, and font style can all affect character reading accuracy. These factors are addressed in *AFGS–87213* and *AFFDL–TR–70–174*.

REQUIREMENT GUIDANCE (4.3.3)

Dot matrix display devices are composed of picture elements (pixels) that can be addressed by various methods to produce alphanumeric characters with an appearance very similar to raster CRT displays. Since dot matrix displays can exhibit failure modes not typically found in CRT displays (e.g., single pixels, groups of pixels, or row and column failures), when using dot matrix display devices, consider in the font design possible display failure modes to ensure reading accuracy. Although the likelihood of certain types of failures can vary depending upon the display device technology and fabrication methods, a survey of dot matrix display vendors shows row and column failures to be of greater concern.

Pixel failures may or may not cause reading errors. If the failures do not affect any of the pixels used to compose the character or if sufficient pixels remain to correctly distinguish the character, then reading accuracy is very high. If pixel failures make a character look unlike any character in the font, or look very similar to another character, then reading accuracy can be degraded substantially. Pixel failures which result in reading errors are considered worst-case failures. Depending upon the criticality of displayed alphanumeric information, such worst-case failures could impact safety and survivability, and therefore mission success.

WRDC/KT has developed a font which enhances character reading accuracy under single row or column failure conditions. This font uses a double pixel stroke width to ensure reading accuracy under such failure conditions. Comparisons between this font and the single pixel stroke width font show about equal reading accuracy without pixel failures (reference *WRDC–TR–90–7009*). With the occurrence of single row or column failures, the two-pixel stroke width font is substantially better than the font used in the previous revision of this document in terms of reading accuracy.

The enhanced font was developed based on a per–character limitation of a 7x9 matrix. This limitation was imposed so that the same amount of text information could be placed on any display device that currently uses the single pixel stroke width font defined in the previous revision of this document. Use of a double pixel stroke width (for a 7x9 matrix size character) results in characters with a stroke width that is 22 percent of character height. *AFGS–87213* recommends that stroke width range from 12 to 20 percent of character height.

Review of the data in *AFFDL–TR–70–174* implies that a stroke width to height of 22 percent should not significantly impact reading accuracy. For example (*AFFDL–TR–70–174* page 171), increasing stroke width to height from 20.1 percent to 30 percent resulted in a maximum degradation in reading accuracy of 3.3 percent and an average degradation of 1.5 percent with characters subtending a visual angle of 22 minutes of arc and brightness contrast ranging from 81 to 94 percent. For characters subtending an angle of 16 minutes of arc, the minimum size for stationary characters in *AFGS–87213*, reading accuracy degrades by a maximum of 7.8 percent and an average of 3.8 percent when increasing stroke width/height to 30 percent under the same brightness contrast and symbol spacing conditions. These error rate increases are substantially less than the 40-percent increase in reading errors when a single row or column fails for the single pixel stroke width font defined in the previous revision of this standard compared to a 3-percent increase in reading errors for double pixel stroke width font. Furthermore, the error rate for the following single pixel stroke width characters with a single critical row or column failure was determined to be greater than 90 percent: E, G, O, P, T, U. It should also be noted that the F–16 data entry display uses a double pixel stroke width font and a stroke width/character height of 22 percent. It is therefore recommended that the font in

Figure 59a be the minimum matrix size used for aircraft cockpit applications. The average reading error rate for this font (without row or column failures) is 0.63 percent with a character display time of only 0.05 second and a visual angle of 26.7 minutes of arc. If display size, resolution, and information density requirements permit, it is recommended that matrix size be increased to implement the recommendations of *AFGS–87213*.

REQUIREMENT LESSONS LEARNED (4.3.3)

4.3.4 Horizontal situation display (HSD). The HSD shall present essential moving map and data frame information to be utilized for flight and combat application. The information presented depends on the requirements of the different modes of operation. *Table I* is a matrix of suggested information requirements and associated symbology for each mode (*Figure 60*).

TABLE I. HSD mode information matrix.

Information Requirements	MODE Take Off	Nav	Tf/ Ta	Weapon Del	Ldg	Figure
Map	X	X	X	X	X	60b
Aircraft Position	X	X	X	X	X	60a
Heading	X	X	X	X	X	60a
Ground Track	X	X	X	X	X	60a
Nav Steer	X	X			X	60a
To/From	X	X			X	60a
Target Points/JTIDS		X	X	X		60a
Target Designator		X	X	X		60a
Fuel Range	X*	X*	X*	X*	X*	60a
Data Frame	X	X	X	X	X	60a
Fuel Range Circle	X*	X*	X*	X*	X*	60a
Time	X	X	X	X	X	60a

NOTE: It is recommended that starred items be removable from the display by means of a declutter control. Symbols that can be deleted by declutter should have a secondary warning when they are deleted because of faulty data.

a. Fuel range circle. This symbol shall be used to display fuel range on the HSD map. The size of the symbol depends on the changing fuel range and map scale factor (*Figure 60a*).

b. Compass rose. The compass rose shall be used to display aircraft heading and shall be driven by the aircraft navigation equipment. In TRACK UP mode, the compass shall rotate to display aircraft magnetic heading when referenced to the index at the top of the display. In NORTH UP mode, the compass shall remain fixed with north located at the top of the display, and aircraft heading is depicted by the aircraft symbol. Tick marks shall be displayed in ________-degree increments with a longer tick mark every ________ degrees, a numeric in place of a tick mark every ________ degrees, and the letters N (north), E (east), S (south), W (west) to represent the four compass directions (*Figure 60a*).

c. Bearing pointer. The bearing pointer shall be used to indicate the magnetic bearing from the aircraft to the selected ground station (VOR, TACAN, ADF, or INS) (*Figure 60a*).

d. Course deviation indicator (CDI) and scale. The CDI shall be used to display the aircraft position (via the aircraft symbol) relative to a selected course. Once the course arrow has been set, the CDI shall rotate with the compass rose. Full-scale deflection (2 dots) on the CDI scale varies as a function of ground station but typically ranges from three-fourths of a degree per dot to five degrees per dot (*Figure 60a*).

e. Aircraft symbol. The miniature aircraft symbol on the HSD shall be used to represent own-ship position with respect to the navigation situation (*Figure 60a*).

f. Heading marker. The heading reference marker shall be used to provide a reference to the desired heading. It is typically used with the autopilot or flight director computer (*Figure 60a*).

g. To/from symbol. The to/from indicator shall be displayed as a triangular-shaped pointer. When the indicator points to the head of the course arrow, it shall indicate that the course selected, if properly intercepted and flown, directs the aircraft to the selected facility (*Figure 60a*).

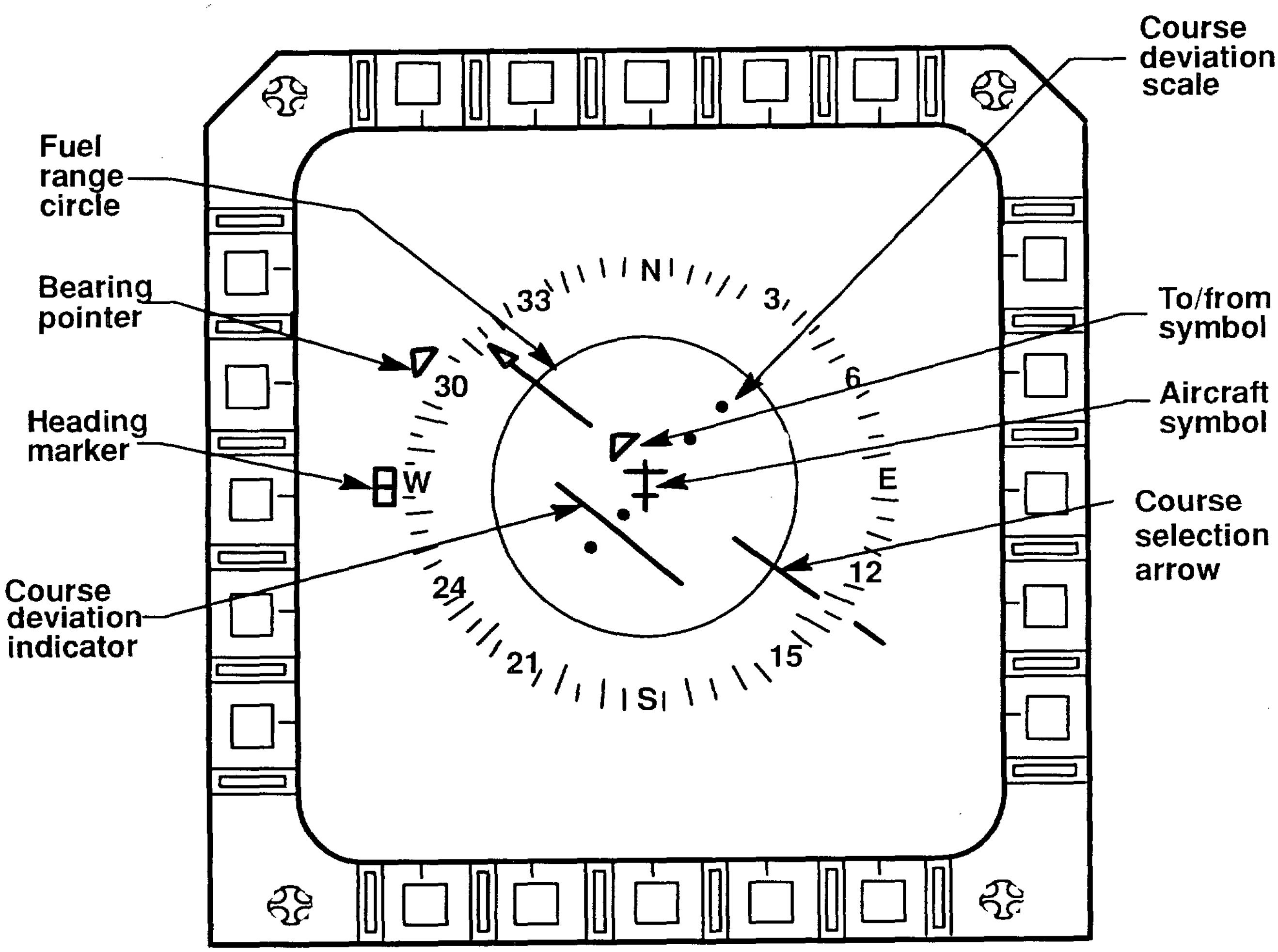


FIGURE 60. a. Typical horizontal situation display.

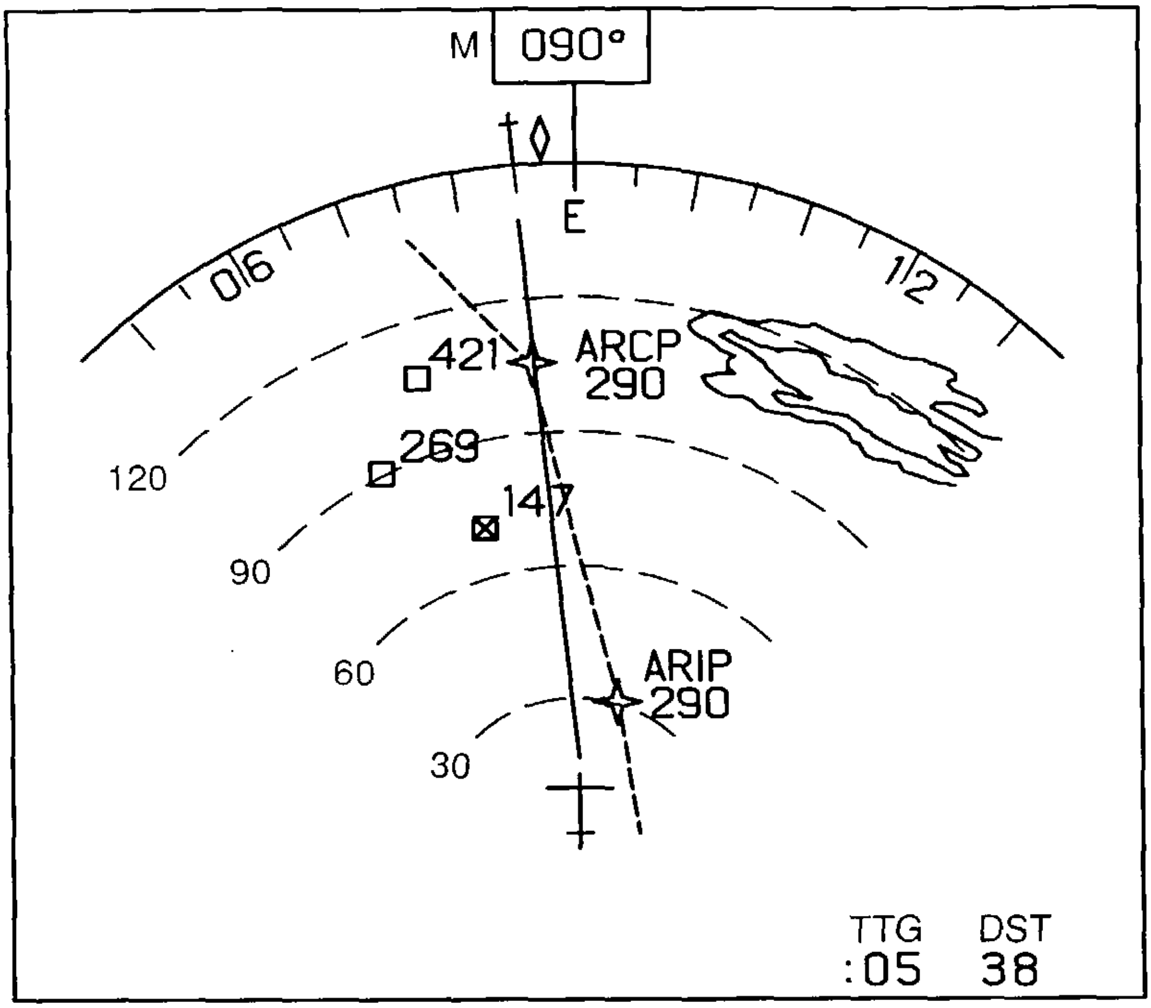


FIGURE 60. b. Arc map display.

REQUIREMENT RATIONALE (4.3.4)

An HSD is a display which aids the crew members in navigation. Basically, it consists of a map presentation, compass rose, miles to go, bearing to destination, ground track, aircraft position, and steering error; it also provides the capability of selecting data charts, emergency procedures, and photographs. Modes generally consist of manual, north-up, course-up, data, test, and off. A certain selection of map scale factors may also be provided. Navigation update can be accomplished with CRT symbols with the map information. Symbols such as check points, various legs of the mission, high-risk areas, ground track deviation, radar homing, and warning, may be used for annotation of a video map. The format shown is complex, partly because it's a direct translation from a mechanical instrument. This layout is recommended to promote commonality and positive training transfer. Changes to this symbol layout may be acceptable if they're proven to be a better design and if they're consistent with current military service's practice.

REQUIREMENT GUIDANCE (4.3.4)

Mission requirements normally dictate the amount and type of information presented on the HSD.

REQUIREMENT LESSONS LEARNED (4.3.4)

4.3.5 Head up display (HUD). The HUD shall present essential flight and combat information. The information presented depends on the requirement of the different modes of operation. *Table II* shows common HUD information requirements and associated symbology for each mode (*Figure 61a* & *61b*).

TABLE *II*. HUD *mode information matrix.*

Information Requirements	MODE Take Off	Nav	Tf/ Ta	Weapon Del	Ldg	Figure
Aircraft Pitch Reference Symbol	X*	X*	X*	X*	X*	11
Aiming Reticle				X		37, 38, 57, 58
Airspeed Display	X	X*	X*	X*	X	12
Allowable Steering Error Circle & Steering Dot				X		39
Altitude Display	X	X*	X*	X*	X	15
Angle of Attack Error/Speed Worm					X	10
Azimuth Steering Line				X		41
Bank Angle Scale	X*	X*	X*	X*	X*	21
Beacon Symbol		X	X	X		42
Bombfall Line				X		43
Breakaway Symbol		X	X	X		44
Character Fonts	X	X	X	X	X	59a,b,c
Climb/Dive Angle Scale	X	X*	X*	X*	X	4, 5, 6, 7, 8
Climb/Dive Marker/Flight Path Marker	X*	X	X	X*	X	45
Continuously Computed Impact Line				X*		30
Flight Director Steering					X	2a,b, 3
Gun Cross				X		46
Heading Display	X	X*	X*	X*	X	19
Horizontal & Vertical Deviation		X	X*		X	24, 27
Lead Computing Optical Sight Line				X		47
Longitudinal Acceleration Cue	X	X	X	X	X	9
Missile Aiming Symbol				X		62a,b,c
Pull-up Anticipation Cue				X		48
Radar Range Scale				X		49
Solution Cues				X		59
Steerpoint Index	X	X	X			42
Target Designators		X	X	X		51, 52, 53
Target Identification Set Laser		X		X		55
Target Locator Line				X		54
Terrain Following Cue			X			56
Vertical Velocity Indicator	X*			X*	X*	18

NOTE: It is recommended that asterisked items be removable from the display by means of a declutter control. Symbols that can be deleted by declutter should have a secondary warning when they are deleted because of faulty data.

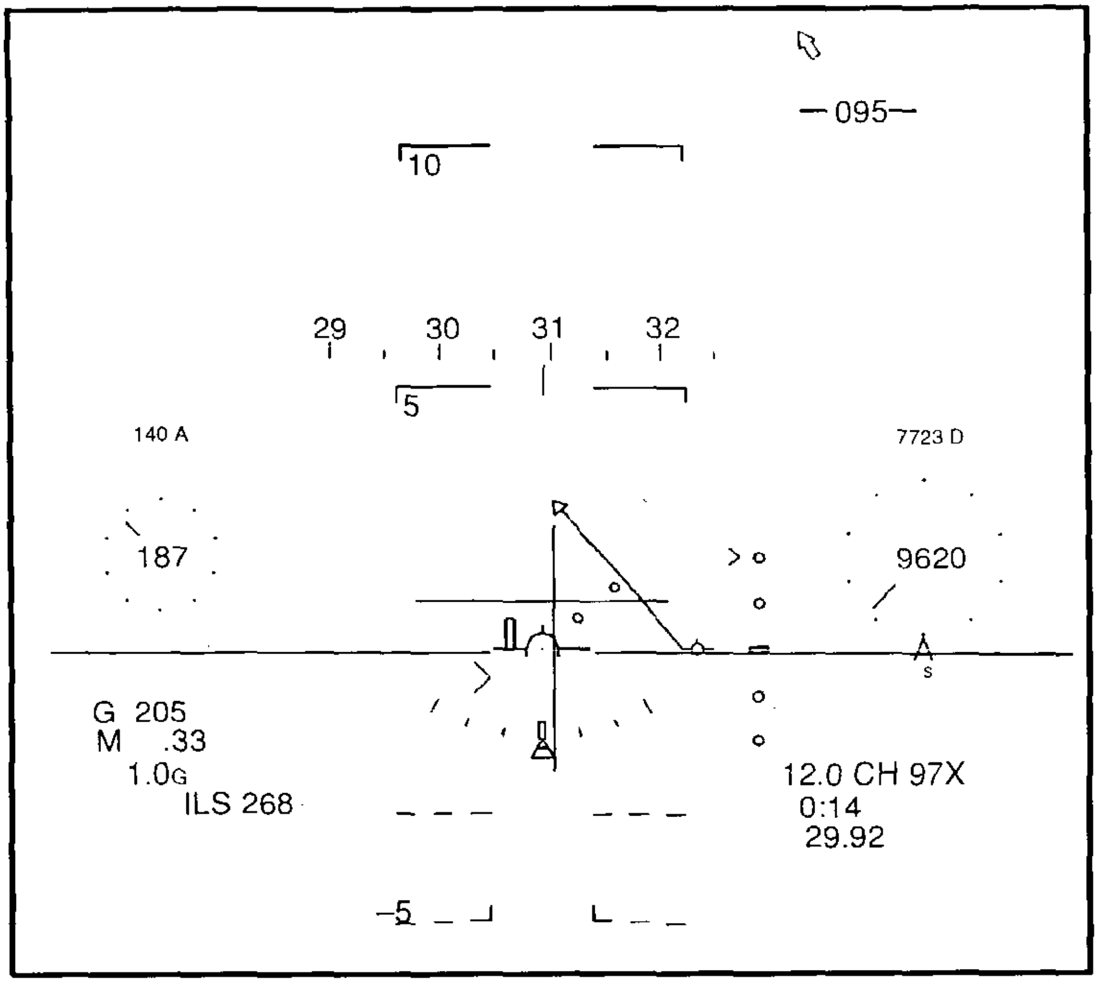


FIGURE 61. a. HUD ILS format.

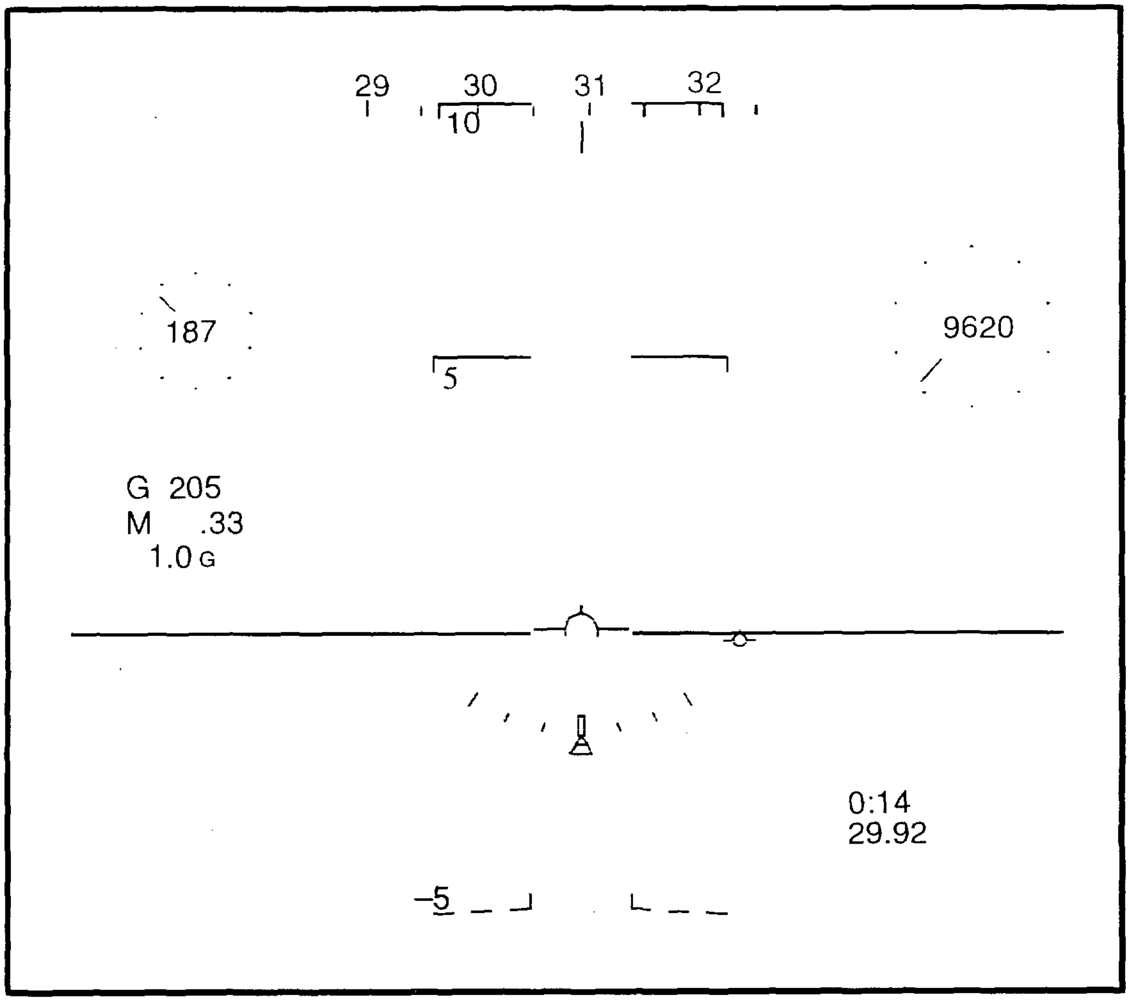


FIGURE 61. b. HUD cruise mode.

REQUIREMENT RATIONALE (4.3.5)

The HUD is a display that projects collimated symbol imagery into the pilot's forward field of view. The technique results in the combination of flight control and weapon delivery information with external visual cues from the scene normally viewed through the windscreen. Specific symbols can be selectable for a given mode of operation. Takeoff, landing, navigation, terrain following/avoidance, and weapon delivery modes may be provided. Video formats such as low light level television (LLLTV), FLIR, or scan-converted radar may be displayed along with symbology.

REQUIREMENT GUIDANCE (4.3.5)

Mission requirements normally dictate the amount and type of information presented on a HUD.

The present practice for navigation, warning, and caution/advisory data presented in the HUD is to display navigation data in the lower right FOV of the HUD, caution and advisory data in the lower left FOV of the HUD, and warning data in the center of the HUD FOV.

REQUIREMENT LESSONS LEARNED (4.3.5)

4.3.6 Missile aiming symbol. *Figures 62a* through *62c* shall be used as applicable for missile seeker head position on both the HUD and head-down display prior to lock-on, during radar lock-on, and after pilot designation or acceptance of the target the missile seeker is locked on.

a. Missile seeker head line of sight (LOS). This symbol shall represent the LOS of the missile seeker head during search (*Figure 62a*).

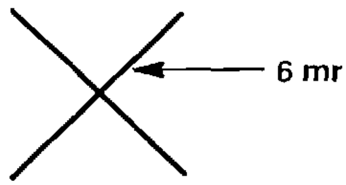


FIGURE 62. a. Missile seeker head LOS.

b. Target lock-on. This symbol shall represent the LOS of the missile seeker head during radar track of the target *(Figure 62b)*.

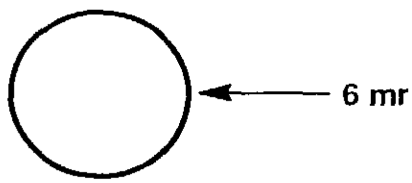


FIGURE 62 b. Target lock-on.

c. Pilot designated target. This symbol shall represent pilot designation or acceptance of the target on which the missile is locked (*Figure 62c*).

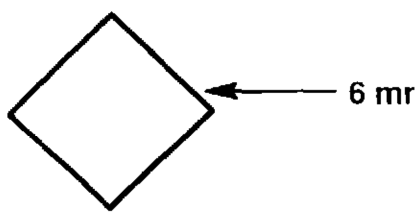


FIGURE 62 c. Pilot designated target.

REQUIREMENT RATIONALE (4.3.6)

This set of symbols provides the pilot with an "attack sequenced" indication of seeker line of sight relative to a target before lock-on, after radar lock-on, and after a missile lock-on (pilot designation).

REQUIREMENT GUIDANCE (4.3.6)

The symbol position on the HUD should identify missile seeker azimuth and elevation in either boresight or slave modes. The diamond should always be reserved for designated targets.

REQUIREMENT LESSONS LEARNED (4.3.6)

4.3.7 Runway reference. This symbol shall be used in landing mode to represent the aim point and touch-down point of a runway (*Figure 63*).

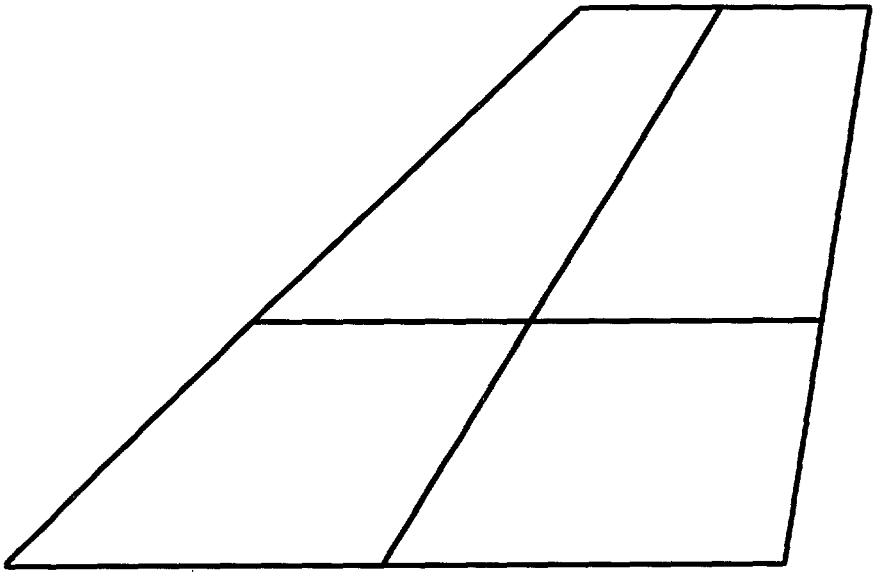


FIGURE 63. Runway reference.

4.3.8 Vertical situation display (VSD). The VSD shall present essential flight and combat information. The information presented depends on the requirements of the different modes of operation. *Table III* is a matrix of suggested information requirements and associated symbology for each mode (*Figures 64a, 64b, & 64c*).

TABLE III. VSD mode information matrix.

Information Requirements	MODE Take Off	Nav	Tf/ Ta	Weapon Del	Ldg	Figure
Acquisition Symbol		X*	X*	X*		34
Aircraft Pitch Reference Symbol	X*	X*	X*	X*	X*	2a,b
Airspeed Display	X*	X*	X*	X*	X*	12
Allowable Steering Error Circle & Steering Dot				X*		39
Altitude Display	X*	X*	X*	X*	X*	15
Angle of Attack Error Display					X*	
Antenna Azimuth & Elevation Markers		X*	X*	X*		40
Attitude Bar	X*	X*	X*	X*	X*	
Azimuth Steering Line				X*		41
Beacon Symbol		X*	X*	X*		42
Bombfall Line				X*		43
Breakaway Symbol		X*	X*	X*		44
Character Fonts	X*	X*	X*	X*	X*	59a,b,c
Course Command, Flight Director		X*	X*		X*	30
Continuously Computed Impact Line				X*		45
Flight Path Angle Display	X*	X*	X*	X*	X*	3
Flight Path Marker	X*	X*	X*	X*	X*	
Gun Cross				X*		46
Heading Display	X*	X*	X*	X*	X*	19
Horizontal & Vertical Bars		X*	X*		X*	
LCOS Line						47
Missile (Aiming Symbol)				X*		62a,b,c
Pull-up Anticipation Cue				X*		48
Radar Range Scale				X*		49
Solution Cues				X*		59
Steerpoint Index	X	X	X			42
Target Designator/Radar Lock-On		X	X	X		51
TISL Reticle		X		X		55
Vertical Velocity Indicator	X			X	X	18

NOTE: It is recommended that asterisked items be removable from the display by means of a declutter control. Symbols that can be deleted by declutter should have a secondary warning when they are deleted because of faulty data.

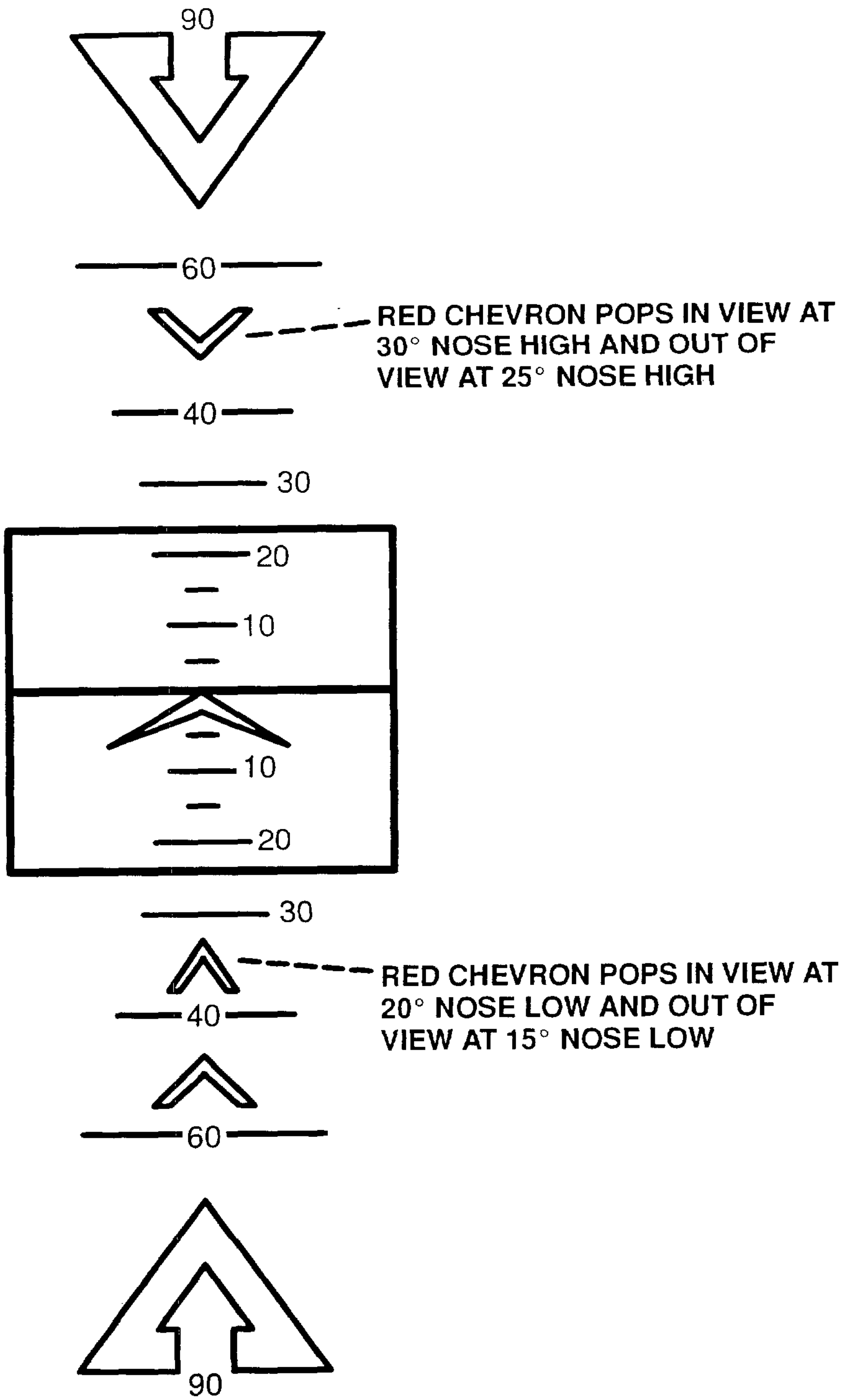


FIGURE 64. a. Electronic attitude director indicator (EADI) display format.

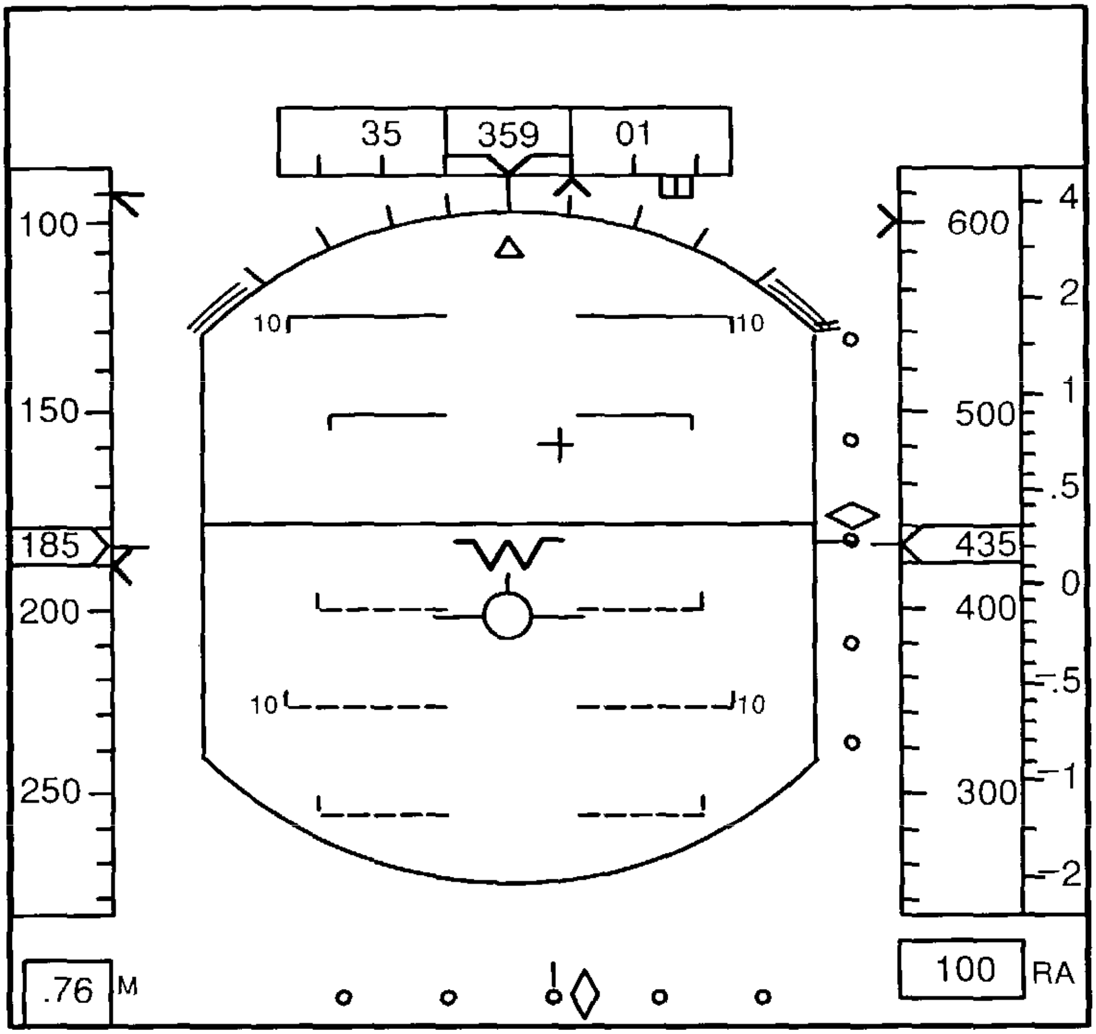


FIGURE 64. b. Transport VSD (landing mode).

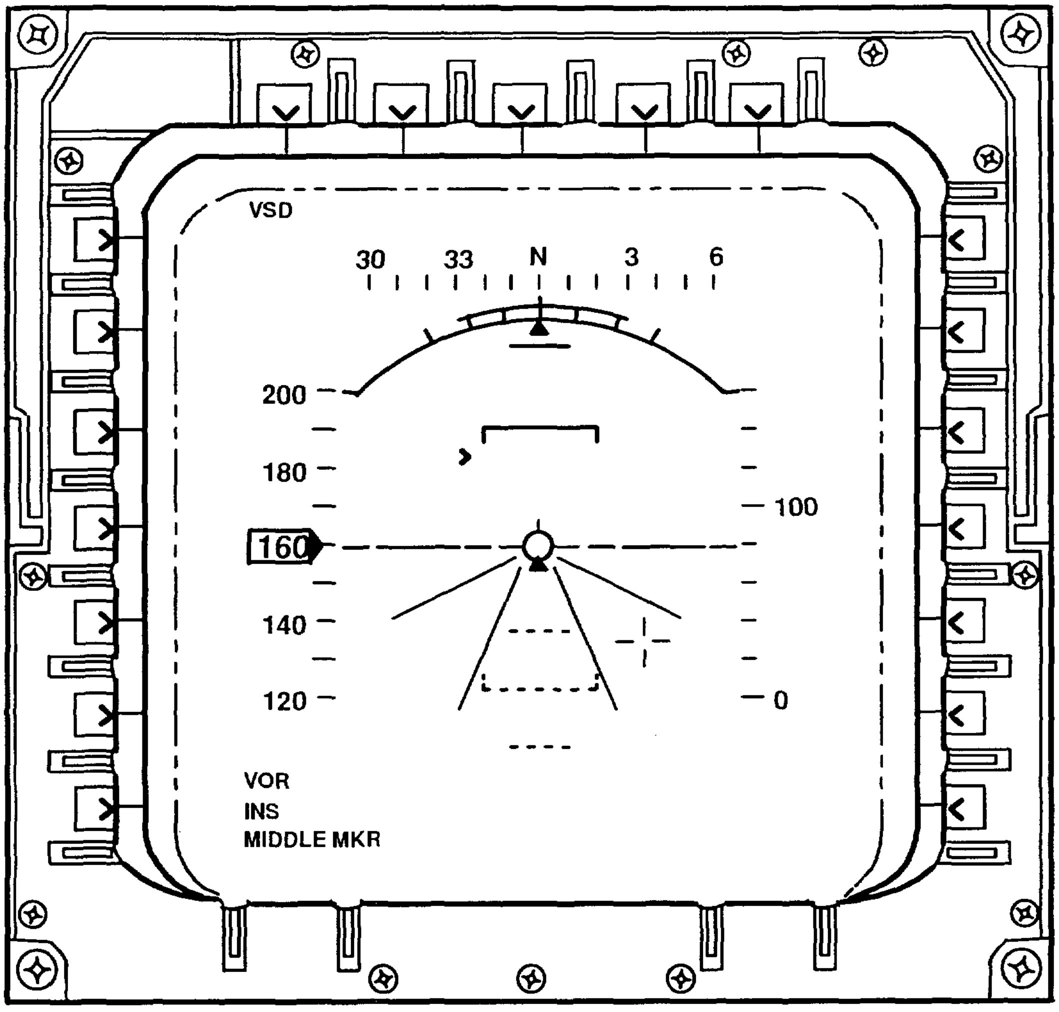


FIGURE 64. c. Typical VSD overlay on FLIR video (not shown).

REQUIREMENT RATIONALE (4.3.8)

The VSD has all of the features of an electronic attitude director indicator (EADI) with the increased capability of displaying sensor data. Additional sensors may consist of LLLTV, IR, attack radar, weapon TV, or terrain following radar. When any mode other than one of the primary EADI modes is selected, the VSD may present basic symbolic information for flight control superimposed on the sensor data.

REQUIREMENT GUIDANCE (4.3.8)

Mission requirements normally dictate the amount and type of information presented on the VSD.

As the development of aircraft display instruments moves away from traditional electro-mechanical instrumentation toward electo-optical displays (i.e., CRT and LCD) special consideration should be given to ensure that vital information is not omitted from the pilot's primary flight information suite. In many cases, not only is the presence of the information important but the way that information is presented can also prove critical. The alarming number of mishaps in which controlled flight into the ground has resulted in the loss of the aircraft and pilot emphasizes the necessity to ensure that such information minimizes the potential for confusion and ambiguity during highly dynamic and high workload conditions.

The following are suggestions to consider when selecting the display characteristics of an EADI.

a. The presentation of attitude information should be as prominent as possible. Current guidance recommends that the attitude surface should be no less than 4 inches in diameter, and preferably 5 inches. Also, this information should be centrally located within the pilot's primary cone of vision on the front instrument panel (see *4.1.1.a*).

b. The field of view of the attitude display surface (or ball) should display at least +/– 45 degrees (total view of 90 degrees) of pitch, particularly for high agility aircraft where potential for spatial disorientation is significantly higher. If the attitude reference provides less than 90 degrees, certain conditions exist (i.e., 45 degrees) in which the pilot has no horizon reference or zenith/nadir reference. If the attitude reference displays less than 45 degrees, a horizon reference should be incorporated to indicate the direction of the horizon when the zero pitch line (i.e., horizon line) is outside the field of view of the display. The horizon line should be changed, however, to inform the pilot clearly that the field of view has been exceeded (e.g., dashed).

c. Consider some cue regarding the magnitude of pitch angle. Many current indicators provide little more than a number to indicate pitch angle. Other means include changing the shade (coloration) of the attitude surface as the pitch changes or increasing the size of the number as the magnitude of the pitch angle increase. Such cues tend to be more intuitive and reduce the time required to interpret information; these should be considered particularly for highly agile aircraft.

d. Consider adding pitch numbers only to one side of the pitch lines to facilitate quick interpretation of roll asymmetry.

e. If a flight path marker is added, it should be no more than one/third the size of the pitch symbol (miniature aircraft). The color of the flight path marker should be clearly different from the pitch symbol.

f. Because these EADIs are used during military missions, consider the crew's use of night vision goggles and laser eye protection.

REQUIREMENT LESSONS LEARNED (4.3.8)

Custodian:
Air Force – 11

Reviewers
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NAVY – EC
DISA – DC-4

Preparing activity:
Air Force – 11

Project No. HFAC-F011

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL–STD–1787B	2. DOCUMENT DATE *(YYMMDD)* 5 APR 96

3. DOCUMENT TITLE
STANDARD PRACTICE FOR AIRCRAFT DISPLAY SYMBOLOGY

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)* (1) Commercial (2) AUTOVON *(If applicable)*	7. DATE SUBMITTED *(YYMMDD)*

8. PREPARING ACTIVITY

A. NAME ASC/ENSI (AF–11)	B. TELEPHONE *(Include Area Code)* (1) Commercial (2) AUTOVON *(If applicable)*
C. ADDRESS *(Include Zip Code)* 2335 SEVENTH ST., SUITE 6 WRIGHT–PATTERSON AFB OH 45433–7809	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church VA 22041–3466 Telephone (703) 756–2340 AUTOVON 289–2340